Mt. Nansen Mine Site, Brown – McDade Pit Desktop Hydrogeological Study

Prepared for

Energy, Mines and Resources
Abandoned Mines Project Office

Submitted by

Gartner Lee Limited

May, 2007

Gartner Lee

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Reference: **GLL 70-103**

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May 22, 2007

Mr. Hugh Copland
Abandoned Mines Project Manager
Government of Yukon, Energy Mines and Resources
P.O. Box 2703 (K-419)
Whitehorse, YT Y1A 2C6

Dear Mr. Copland:

Re: GLL 70-103 – Mt. Nansen Mine Site – Brown-McDade Pit Desktop Hydrogeological Study

We are pleased to provide our Final report entitled "Mt. Nansen Mine Site, Brown - McDade Pit Desktop Hydrogeological Study". We feel this report contributes to a better understanding of the hydrogeological conditions surrounding the Brown-McDade open pit based on field observations and hydrogeological concepts.

Please do not hesitate to contact me at (867) 633-6474 ext. 5727 should you have any questions. We thank you for the opportunity to work on this very interesting project.

Yours very truly,
GARTNER LEE LIMITED

Jonathan Kerr, M.Sc., P.Geo.
Hydrogeologist

JK:mm
Attach.

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1. Introduction

1.1 Background

Gartner Lee Limited (GLL) was contracted by the Yukon Territorial Government to assess the probable fate of seepage leaving the Brown-McDade Pit via the groundwater pathway and comment on the potential flow regime changes to the pit by partially backfilling the pit with benign waste rock. This study is intended to build upon previous work conducted by Gartner Lee and others, that have primarily focused on data collection rather than data interpretation. Raw data that has been collected as part of earlier investigations has not been included in this report. The reader is directed to the reference section for a complete listing of data sources. A description of the site history, including details of the owner/operator and site status is provided in GLL 2004 and GLL 2005.

1.2 Study Objectives

The primary objectives of this study were to:

1. Develop and refine the Conceptual Groundwater/Surface Water Flow Model in the vicinity of the Brown-McDade Pit to provide an increased level of understanding the potential for environmental impacts to critical surface water receptors (i.e., Dome Creek, Pony Creek, and or Victoria Creek).
2. Assess the potential effects of partially backfilling the open pit with benign waste rock.

As discussed, the focus of the Conceptual Model is to assess the fate of poor water quality leaving the Brown McDade Pit. The intention of this work is to create a framework and rational for future site characterization and ultimately site closure recommendations. By providing a better understanding of the pit flow regime it is anticipated that the recommendations of this report will be coupled with site-specific geochemical information, so that geochemical implications of a change in pit flow regime can be assessed. For example, if seepage into the pit from Pony Creek can be reduced by modifying the creek bed and/or by constructing a grout curtain in the shallow fractured bedrock, the effect may be a significant decrease in pit water volume (i.e., lower pit water levels). However, this may result in a higher concentration of heavy metals in the pit seepage water leaving the pit and potentially a greater impact to the environment.

2. Conceptual Flow Model Development

The following sections provide context and rational for the development of the Conceptual Groundwater/Surface Water Flow Model. A summary of the overall Conceptual Model is provided in Section 2.5. A site map of the area is provided in Figure 1.

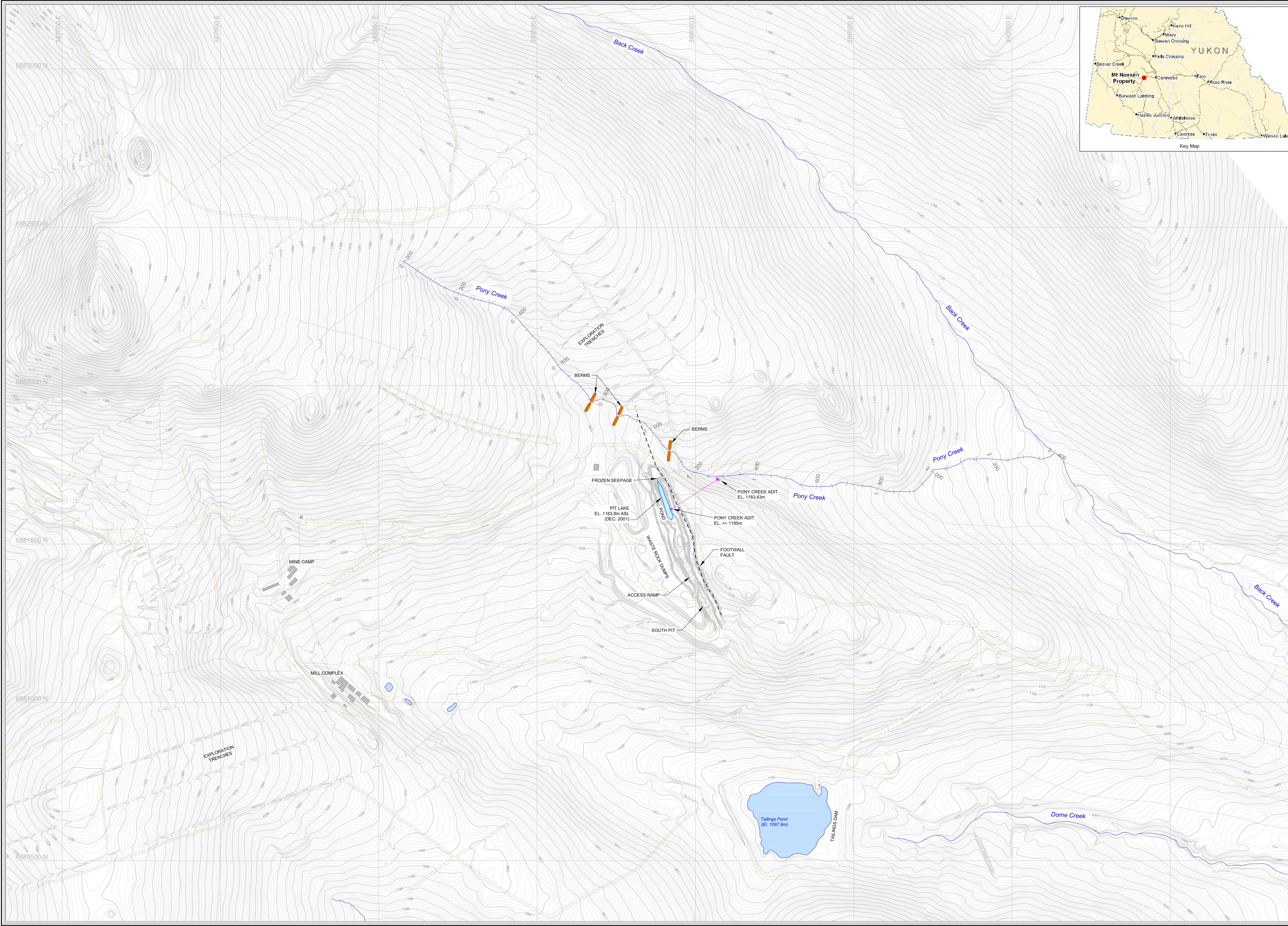
2.1 Site Visit and Observations

A visit to site was conducted on February 21, 2007 to observe the relationship between the Brown-McDade open pit, topography and groundwater recharge and discharge areas. The field visit was also used as an opportunity to verify the location and construction (i.e., diameter, depth, flow rate, etc.) of an artesian well (Figure 1), which was used historically as a source of mine water. Whereas previous site visits focused primarily on investigating the geochemistry of the open pit and developing a water balance, this site visit was conducted with a view toward characterizing, on a catchment and regional scale, the hydrogeology and hydrology of the Brown-McDade open pit. A photo log of the site conditions at the time of the visit is presented in Appendix A.

During the site visit important features were inspected including the tailings facility, the Brown-McDade open pit, groundwater discharge features on the north wall of the pit, the Pony Creek catchment immediately upstream, beside, and downstream of the pit, and the artesian well located at the confluence of Back Creek and Victoria Creek. Overall, the site exhibits high to moderate relief, with topographic highs of approximately 1510 mASL to the west and topographic lows of 1015 mASL near the confluence of Dome Creek and Victoria Creek to the east. Bedrock is exposed on most topographic highs, with colluvium, glacial and organic sediments mantling bedrock throughout the study area. Fluvial deposits are prevalent lower down in the valley bottoms where stream gradients are low. These lower reaches are typically where sustained year round stream base flows occur.

2.1.1 Observations at Brown McDade Pit

A large icing was observed during the site visit at the point of groundwater discharge mid way up the north wall of the Brown-McDade pit (photos in Appendix A). This icing covered the majority of the north wall of the pit, east of the exposed exploration drifts. These observations are consistent with those made during a GLL site visit conducted in February 2004 (GLL 2004). There are two openings at the north end of the pit that are remnants of historic underground exploration and mining activities. During the 2007 site visit, an accumulation of ice (i.e., glaciating groundwater seepage) was observed on the floor of the westernmost stope opening. The eastern stope was not inspected as it was completely filled with ice. It appeared that most of the water in this area had entered the easternmost stope via shallow (frost-shattered) bedrock from above (i.e., mid way up the north pit wall). The seepage water then appeared to flow toward the western stope and on into the pit lake, where a large ice ramp had formed. This apparent seepage water flow path is consistent with observations made during unfrozen periods where free flowing water enters the pit in a similar location and in a similar flow sequence or pattern (GLL 2005).



Legend

- Contour -Major 5m
- Contour -Minor 1m
- Drainage
- Lake / Pond
- Building
- Road / Trail
- Inferred Fault (By B.Y.G. Natural Resources Inc.)
- Existing Berm

Map Sources / Notes:
Topographic data by The Orthoshop, based on 1998 aerial photography at 1:50,000 scale.
Brown McDade Pit survey by Underhill Geomatics Ltd, Drawing 281-05B Dated March 18, 2003.

NTS Map Sheet 115 I / 03

N W E S

0 25 50 100 150 200 m

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UTM Zone 8 N, NAD83

File Name: 70103_By2_01_PlanMap_Sect.dwg
Reviewed by: RM/JK Prepared by: AS/PW
Date Issued: April, 2007 Project Number: 70-103

Yukon Territorial Government

Mt. Nansen Mine
Hydrogeological Conceptual Model
Location: Near Carmacks, Yukon

Site Location Map

Gartner Lee

Figure 1
Version 1

2.1.2 Artesian Well Description

An artesian well located near the confluence of Back Creek and Victoria Creek (some 2.2 km down valley) was historically used for mill supply water and currently provides potable water for domestic purposes. At the time of the site visit, the well consisted of a 10-inch well casing with a 4-inch drop pipe connected to a 40 HP pump that was not operating. A smaller Grundfos submersible pump with a 1-inch drop pipe was operating during the site visit however, and appeared to be pumping at a rate that maintained the elevation of water in the well below ground surface. This water was being pumped to Victoria Creek at the time of inspection. The pumping water level was 1.54 m below the top of casing. It is unclear if the well is screened in surficial deposits or in bedrock; however, the depth of the artesian well is reportedly 30.5 m (100 feet). Groundwater quality results from the well (unpublished data, provided by Yukon Government) are provided in Appendix B and indicate relatively good potable groundwater. The only exceedance was for total iron, which marginally exceeded the non-health related aesthetic guideline value of 0.3 mg/L. The dissolved iron concentrations however were found to be below the guideline indicating that the total metal sample could have had a positive bias, commonly the result of silt or fine sand contained in the well water sample. The detection limits for other parameters including antimony, arsenic, cadmium, lead and selenium were not sufficiently low enough to permit a direct comparison with drinking water quality guidelines.

2.2 Reference Data

The following data sources were reviewed in order to assess the hydrogeology of the area surrounding the Brown-McDade open pit:

a) Topographic mapping;
b) Geologic mapping (BYG, 1994);
c) Pit lake levels (YTG, ongoing);
d) Surface water levels (GLL, 2004);
e) Flow measurements in Pony Creek (GLL, 2004);
f) Pit chemistry (GLL, 2004; YTG);
g) Pony Creek Adit Plugging Terms of Reference;
h) Initial Environmental Evaluation (BYG, 1994); and
i) Personal communication with H. Copland (2007).

2.3 Geologic Framework

2.3.1 Surficial Geology

During July 1994, an exploratory drilling program was conducted within the Dome Creek catchment as part of the tailings pond site selection process. Based on the result of this investigation, overburden typically ranges in thickness from < 1 m on upland bedrock outcrops to in excess of

20 m in the centre of the Dome Creek valley bottom (BYG 1994). The area is classified as exhibiting discontinuous permafrost and drill refusal as a result of frozen ground was noted in numerous drill logs, particularly at locations along north facing aspects and within the upper reaches of Dome Creek. A more recent observation made during the installation of a heat siphon below the tailings pond, found permafrost present across the entire unconsolidated sediment package, perpendicular to Dome Creek (C. Hamilton pers., comm. 2007)

A layer of glacial till overlies bedrock in the deepest part of the Dome Creek valley which consists of a silty fine sand with numerous angular to sub-rounded pebbles and cobbles (BYG 1994). Overlying the glacial till is a silty fine to medium sandy material up to approximately 15 m thick with 10 to 40% fine content. Organic horizons were observed in several boreholes and test pit locations. A layer of moss approximately 20 to 30 cm thick covers a sandy material in many lowland areas. Peat up to 0.9 m thick has also been observed.

Given the observations of permafrost in the unconsolidated sediments in the vicinity of the tailings impoundment, it is assumed that there will be no groundwater flow in the alluvial package in the upper portion of Dome Creek. However it is interpreted that the presence of unfrozen and unconsolidated materials within the Dome Creek valley bottom (particularly in the vicinity of the tailings pond and in the lower reaches of Dome Creek) collectively behave as a valley bottom "aquifer", which provides a role in maintaining the observed year round base flows in lower Dome Creek. It is believed that the low-lying reaches of this drainage basin, receive lateral recharge from the surrounding upland bedrock aquifer system, effectively creating a groundwater discharge zone. The shallow observed presence of a near ground surface water table in this low low-lying area supports this conceptual flow model. A further discussion regarding the importance of this valley bottom aquifer system is provided in subsequent sections.

Pony Creek however is part of a slightly smaller catchment area, and surficial unconsolidated deposits, particularly in the upper and middle reaches of the catchment are not extensive (i.e., thin and not wide, transverse to the creek). Bedrock appears to be very close to the creek bed surface, as numerous bedrock exposures are visible. This observation is supported by the surface exploration trenching activities that have been conducted in this upper part of the drainage basin. Additionally, it has been observed that Pony Creek completely freezes to bottom during winter months, which is likely a result of low free flowing groundwater discharge availability in these thin, near creek, valley sediments. As the distance from the headwaters of Pony Creek increases, the presence and extent of surficial deposits become more evident as fluvial deposits occur below an elevation of 1,130 m (creek distance chainage 1, 900 m, Figure 1).

2.3.2 Bedrock Geology

The study area was not glaciated during the Pleistocene glaciations and as such, the shallow bedrock is heavily fractured due to freeze-thaw action. This weathered surface is thicker (i.e., deeper) than in areas that were glaciated during Pleistocene times.

The bedrock geology of the Mount Nansen property consists of highly deformed Upper Paleozoic or older gneiss and schists that are intruded by Upper Triassic and Juassic granodiorite and syenite batholiths (BYG 1994). Mid to late Cretaceous mafic to felsic stocks, dykes, volcanic flows and pyroclastic rocks have also intruded into the other rock types. In addition, a series of subparallel anastomosing veins occur in a 2.5 km wide belt that bear precious metals and extend the length of the property. The veins strike northwesterly and exhibit steep northeasterly to moderate southeasterly dips and crosscut all rock types.

The Brown-McDade zone lies at the southeasterly end of the belt and measures 500 m long by 200 m wide, consisting of quartz veins and associated feldspar porphyry dykes developed in the hanging wall of a prevalent footwall fault. The footwall fault strikes 160 degrees and dips between 50 and 70 degrees to the southwest, cutting obliquely across a contact between granodiorite and metamorphic rocks.

The strongest mineralization was found in a 3 to 40 m wide band located in the hanging wall of the footwall fault and surrounding quartz veins. Gougy altered wall rocks are commonly found associated with the quartz veins and are reported to exist within the identified footwall fault (BYG, 1994). Supergene weathering has oxidized near surface sulphide minerals, with the depth of oxidation ranging from 5 m at the north end of the zone to at least 75 m at the south end.

As noted by BYG (1994) it is believed that the gouge and alteration associated with the footwall fault effectively provides a low permeability groundwater boundary, which can reduce or cut off groundwater flow across (i.e., orthogonal to) the fault zone (BYG 1994). The location of the footwall fault is illustrated in Figure 1.

2.3.3 Bedrock Control on Groundwater Flow

Based on the geological descriptions provided, it is believed that the highly frost shattered nature of the upper bedrock surface in combination with the fractured nature of the ore body, likely provides a higher permeability zone along the shallow, western side of the footwall fault, at the north end of the pit. This more permeable zone may act as a preferential groundwater flow path (parallel to the fault axis and parallel to geologic structure) from under Pony Creek, laterally downward, and into the pit lake. Additionally, the footwall contact of the ore zone is either directly against or within a few metres of a competent unaltered granodiorite located on the east side of the pit. It is possible, that these geological structures are providing a low permeable barrier to groundwater flow, and are affectively “diverting” seepage water from under Pony Creek, into the pit. This may explain why the eastern most stope along the north pit wall (i.e., that stope which is closest to the foot wall fault) is the primarily location where seepage water daylights prior to cascading downward and into the pit.

In summary, the geologic structure and associated rock properties (i.e., relative difference in permeability) are likely preferentially directing Pony Creek subsurface leakage into the Brown McDade Pit. Once in the pit bottom, the bedrock is more massive and less permeable and the seepage water accumulates and slowly discharges to the underlying bedrock aquifer. The bedrock aquifer underlying the pit, (i.e., the lower portion of the ore body) is also alerted and is believed to be higher in permeability than the more competent bedrock. Therefore the flow path of seepage water out of the pit through this deeper bedrock system could potentially follow a similar groundwater flow trend, (i.e., along geological structure), downward towards the unconsolidated Dome Creek valley aquifer system). At this time however this is an interpretation only. To assess the Conceptual Flow Model, a shallow, bedrock-monitoring well could be completed between the north and south pit to measure bedrock aquifer gradients in this southeasterly direction. A further discussion of the bedrock aquifer system is provided in the subsequent sections.

2.4 Hydrological and Hydrogeological Framework

2.4.1 Pony Creek

Surface runoff originating in the vicinity of the Brown-McDade open pit drains to either the Pony Creek or Dome Creek catchment areas, and then into Back Creek and Victoria Creek. The pit itself captures surface runoff from the pit walls and a small area surrounding the pit that is not drained away by ditches located around the pit. It appears that a significant component of water reporting to the pit however is via groundwater seepage at the north end, which enters midway up the north pit wall through fractured bedrock on the western side of the footwall fault. Based on an elevation survey (GLL 2004), it is interpreted that the most likely source of this water is from seepage below Pony Creek.

Pony Creek is an ephemeral stream and has flow measurements that are quite variable along its length, with the stream running entirely below surface at some locations (GLL 2005). Additionally, observations made during the winter of 2004, indicated that Pony Creek freezes completely to bottom from late fall through early spring (GLL 2005). On an annual basis it is estimated the Pony Creek seepage component represents approximately 75% to 80% of the total water reporting to the pit (calculated from GLL 2005, Pit Water Balance). This large percentage of the total pit water "input" budget, strongly suggests that Pony Creek is a losing stream (i.e., recharging to groundwater) within its upper and middle reaches (i.e., the high alpine, where the stream has a high gradient, namely above an elevation of 1,130 m). However, lower in the valley bottom, where the stream gradient is less and accumulations of unconsolidated fluvial deposits occur (i.e., below and elevation of 1,130 m), the stream overall likely receives flow inputs from groundwater discharge.

2.4.2 Dome Creek

Continuous stream flow measurements have not been recorded from Dome Creek, however throughout this past winter, water has been continuously pumped from a pond at the toe of the tailings pond into lower Dome Creek at a rate of approximately 200 m^3/day or 2 L/sec. The quality of this water has been reportedly good, meeting applicable discharge criteria (per. comm., H. Copland, 2007).

As discussed, the extensive continuous permafrost in the unconsolidated sediments in Upper Dome Creek, limit the potential for groundwater discharge to Dome Creek in the upper reaches. It is believed that because of the permafrost, groundwater will flow in either the unfrozen unconsolidated sediments below the permafrost or in the shallow bedrock, generally parallel with the Dome Creek axis. The groundwater will then potentially daylight to Dome Creek in the lower reaches where the permafrost become discontinuous. In the lowest reaches of Dome Creek, it is interpreted that the unfrozen, unconsolidated sediments will act as a shallow water table aquifer with groundwater discharge to Dome Creek, forming base flows in the lower reaches year round.

Additionally, the construction and operations of the tailings pond has likely created an unfrozen zone below the pond and dam. This feature is referred to as a talik. The talik under the dam and pond is likely allowing deeper groundwater confined below the valley bottom permafrost to now discharge. Therefore, the flow observed at the toe of the tailings impoundment, likely represents a combination of tailings seepage and groundwater discharge. There is potential that groundwater flow from Brown McDade Pit, flowing preferentially along geological structure, is discharging to this talik and toe seepage area.

2.4.3 Discussion of Groundwater Surface Water Interaction

As is typical in mountainous alpine environments, the transition from a groundwater recharge zone to a groundwater discharge zone is variable. In general terms groundwater discharge would be expected to occur predominantly lower down in the catchment drainage network, where topographic relief is less and the presence of fluvial filled valleys bottoms becomes prevalent. This generalization is supported by the presence of year round stream flows observed to occur in the lower reaches of Dome and Victoria Creek (i.e., upwelling of warm groundwater) and the presence of an artesian well (i.e., upward groundwater gradients) near the confluence of Victoria Creek and Back Creek.

It is recognized that poor water quality is seeping out of the Brown McDade Pit, and represents a year round approximate seepage rate of 0.2 L/sec (GLL 2005). The flow path this water takes through the subsurface is very difficult to determine precisely. Yet it is recognized that this water is part of a large scale groundwater and surface water flow system and therefore impacts to the environment have been assessed on a “catchment level” basis. Furthermore, the relative amounts of water that discharge via the tailings impoundment and seepage versus groundwater discharge to the Dome Creeks lower reaches is uncertain.

It is recognized that preferential groundwater pathways occur in fractured bedrock. However in the absence of detectable, poor water quality seepage features flowing directly into Dome or Pony Creek, at elevations lower than the pit lake elevation, it is likely that the groundwater flow paths leaving the pit report to a deep bedrock aquifer system. The bedrock aquifer system eventually recharges to the down valley, unfrozen, unconsolidated, aquifer systems (the same aquifer systems which provides recharge and maintain base flow throughout the year in Dome and Victoria Creeks). Within these groundwater discharge zones, it is difficult to locate specifically where potential groundwater flow lines inevitably daylight, particularly given the known complexity associated with groundwater surface water flow interactions (Conant Jr. 2001).

Figure 2 provides a schematic of how groundwater and surface water, within the unfrozen reaches of the stream valley bottom groundwater discharge zone, interact. In general terms, Figure 2 outlines five basic flow interactions. Notably, it is possible for groundwater flow lines to discharge and effectively mix directly within or below the surface water system and or remain completely isolated. It is also expected that increased levels of mixing/dilution will occur within these groundwater discharge zones as groundwater flow lines typically converge causing a local increase in dispersion. Such complex interactions therefore may effectively eliminate the ability to measure or detect point-source surface water quality impacts, particularly, if the relative pit water discharge represents a small percent of the overall water flowing through the system.

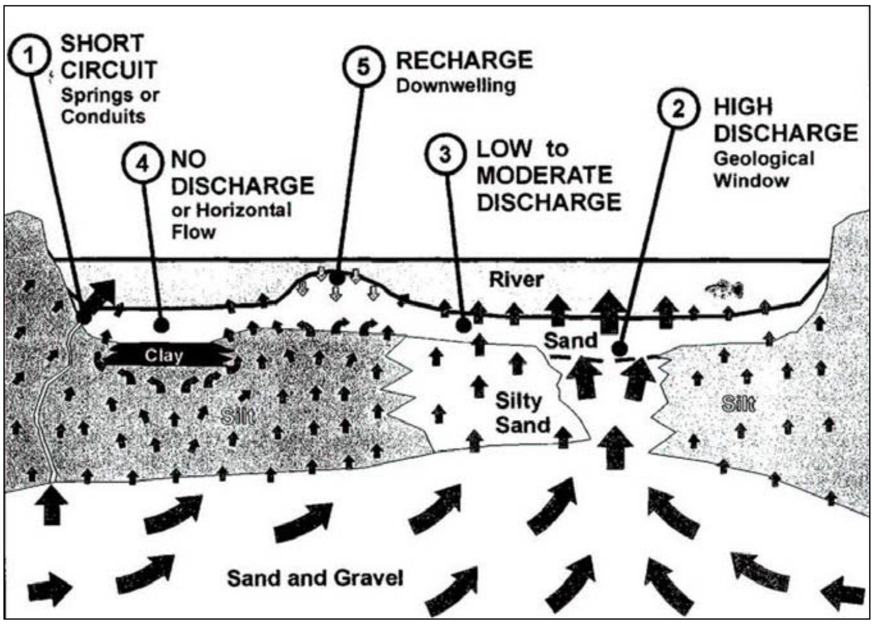


Figure 2. Groundwater / Surface Water Interactions (Conant Jr. 2001)

2.4.4 Brown McDade Pit Leakage

The Yukon Government has recorded pit lake elevations since 2001 using a permanently installed pressure transducer and data logger. These data are regularly downloaded by YTG and has been analyzed during the development of the preliminary pit water balance (GLL 2004).

The volume of groundwater leaving the pit has been estimated using the observed rate of "pit water level decline" during the winter and early spring months. It is recognized that the volume of water discharging to the groundwater system beneath the pit likely fluctuates on a seasonal basis, as the pit water level and wetted surface area of the pit change with time. However, the range in net groundwater seepage out of the pit is estimated to be 470 m^3/month and 600 m^3/month, with an averaged rate of 535 m^3/month or 0.2 L/sec (GLL 2005). It is also important to note that the observed groundwater seepage out of the pit during winter months indicates that this flow system remains active/unfrozen and therefore occurs year round.

The Darcy Equation (Appendix C) was used to estimate the approximate average hydraulic conductivity of the bedrock aquifer directly surrounding the pit bottom. The average measured seepage rate out of the pit (0.2 L/sec) was used in combination with the approximate pit bottom surface area (1,905 m^2, estimated using the pit survey information). Assuming a gravity drained pit condition and a hydraulic gradient of 1, a pit bottom hydraulic conductivity of 1 x 10^{-7} m/sec was estimated.

In the development of the Conceptual Flow Model, and in the absence of monitoring wells, evidence has been gathered and assessed to determine if the pit lake water level represents the regional groundwater table. Based on the following observations there is potential that the pit water level represents a perched feature:

1. The site is located within a high-relief mountainous environment and lies within a very small catchment area. Subsequently, there is a very little groundwater recharge available and in conjunction with the steep terrain; a relatively deep bedrock water table (i.e., below the pit bottom elevation) is likely. Additionally, the observed frozen ground condition within the alpine catchment areas during winter months reduces available water for infiltration (i.e., recharge).
2. The absence of up-gradient groundwater seepage evidence into the pit along the eastern pit wall and or pit shoreline (i.e., staining, visual presence of a wetted rock face etc.). The exception however is the well-documented seepage that occurs within the shallow fractured bedrock, located midway up the north pit face (GLL 2005). As discussed, this represents the largest component of the source of pit water (75 to 80%) and is most likely provided by seepage water short-circuiting from leakage below Pony Creek.
3. The absence of groundwater during the completion of the underground workings prior to open pit mining. Based on the estimated hydraulic conductivity of the low portion of the pit bedrock (10^{-7} m/sec) it would be likely that if the regional water table were intercepted a pit water management plan would have likely been required. Again, the exception to this observation however, occurred in the vicinity of the stope extension at the north end of the pit, where seepage occurred from the stope roof (i.e., from above).

Although the evidence presented suggests the pit lake may be a perched water feature, for the purposes of this assessment, a conservative approach has been taken whereby the pit lake is assumed to represent the regional water table. This assumption subsequently produces a ‘worst case’ flow scenario whereby using the pit lake elevation as a reflection of the regional groundwater table, maximum groundwater gradients will be assessed in relation to nearby surface water elevations (i.e., creek elevations), and the saturated flow equations (Appendix C) would be applied to produce the shortest predicted travel times.

2.5 Conceptual Flow Model

The development of the Conceptual Groundwater/Surface Water Flow Model has focused on the consideration of potential impacts associated with groundwater discharge of poor water quality out of the Brown McDade pit into the surrounding environment. The Conceptual Model is based on a culmination of information discussed, including pertinent site observations, site elevation data, geological data, historical geotechnical data and a terrain analysis. In summary, the following outlines the important components (step by step) of the Conceptual Flow Model:

1. Pony Creek, in its upper reaches (i.e., chainage 0 to 1, 900 m – Figure 1) is a loosing stream, and provides recharge to the shallow fractured (permeable), near surface bedrock system.
2. The existing geological structure at the site, including the shallow fractured bedrock underlying Pony Creek, extends southeast and parallel to where the ore body was located, prior to mining. The shallow fractured bedrock system likely provides a "preferential flow path" for Pony Creek seepage to "short circuit" into the Brown McDade pit.
3. Along the eastern side of the Brown McDade pit, is a low permeable Footwall Fault, which parallels the pit and extends northwest under Pony Creek. This geological structure is believed to provide a low permeable barrier to groundwater flow, which could effectively be "diverting" seepage water from under Pony Creek in the direction of the pit.
4. Small surface water ponds on Pony Creek created by exploration trenches likely encourages infiltration to the shallow groundwater system, and potentially exacerbates groundwater seepage and flow to the pit.
5. The bedrock aquifer system underlying the Brown McDade pit lake likely has a lower permeability (i.e., hydraulic conductivity) than the upper fractured bedrock system and is estimated to be 10^{-7}m/sec. The average seepage rate out of the pit is estimated to be approximately 0.2 L/sec.
6. Given the fractured nature of the ore body, the hydraulic conductivity estimated at the base of the pit is likely higher than the surrounding competent bedrock, and trends in a similar orientation to the footwall fault (i.e., northwest/southeast). It is interpreted, that groundwater seepage out of the pit likely is controlled by this geological structure (i.e., anisotropic flow) and that seepage (i.e., groundwater flow out of the pit) is likely towards the Dome Creek Valley bottom. The observed groundwater "loosing" condition in Pony Creek and the corresponding groundwater "gaining" condition in Dome Creek support this conceptual model.
7. Given the identified pit water level and stream behaviour in each of the two adjacent catchment basins, a regional groundwater elevation map has been constructed as illustrated in Figure 3. Although the pit lake is likely a perched

water feature, as a conservative approximation, it has been considered a reflection of the regional water table to provide estimates of groundwater gradients and flow directions.

8. The unconsolidated sediments in the upper reaches of Dome Creek are permanently frozen and likely limit groundwater discharge to the upper reaches of Dome Creek. The exception is the likely presence of a talik under the tailings impoundment and the tailings dam that may allow groundwater to discharge along with tailings pond seepage. The lower, unfrozen reaches of the Dome Creek valley bottom aquifer represents an active year round groundwater discharge zone.
9. The deep bedrock aquifer in the vicinity of the Brown McDade pit is likely recharging (Figure 3) the unconsolidated valley bottom aquifer systems, namely into the central reaches of Dome Creek and to a lesser extent the lower reaches of Pony Creek (i.e., below chainage 1, 900 m).
10. Recharge from the valley aquifer system to the surface water system is complex (Figure 2) and may effectively eliminate the ability to measure or detected point source surface water quality impacts, particularly, when the relative pit water discharge represents a small percent of the overall water flowing through the system.

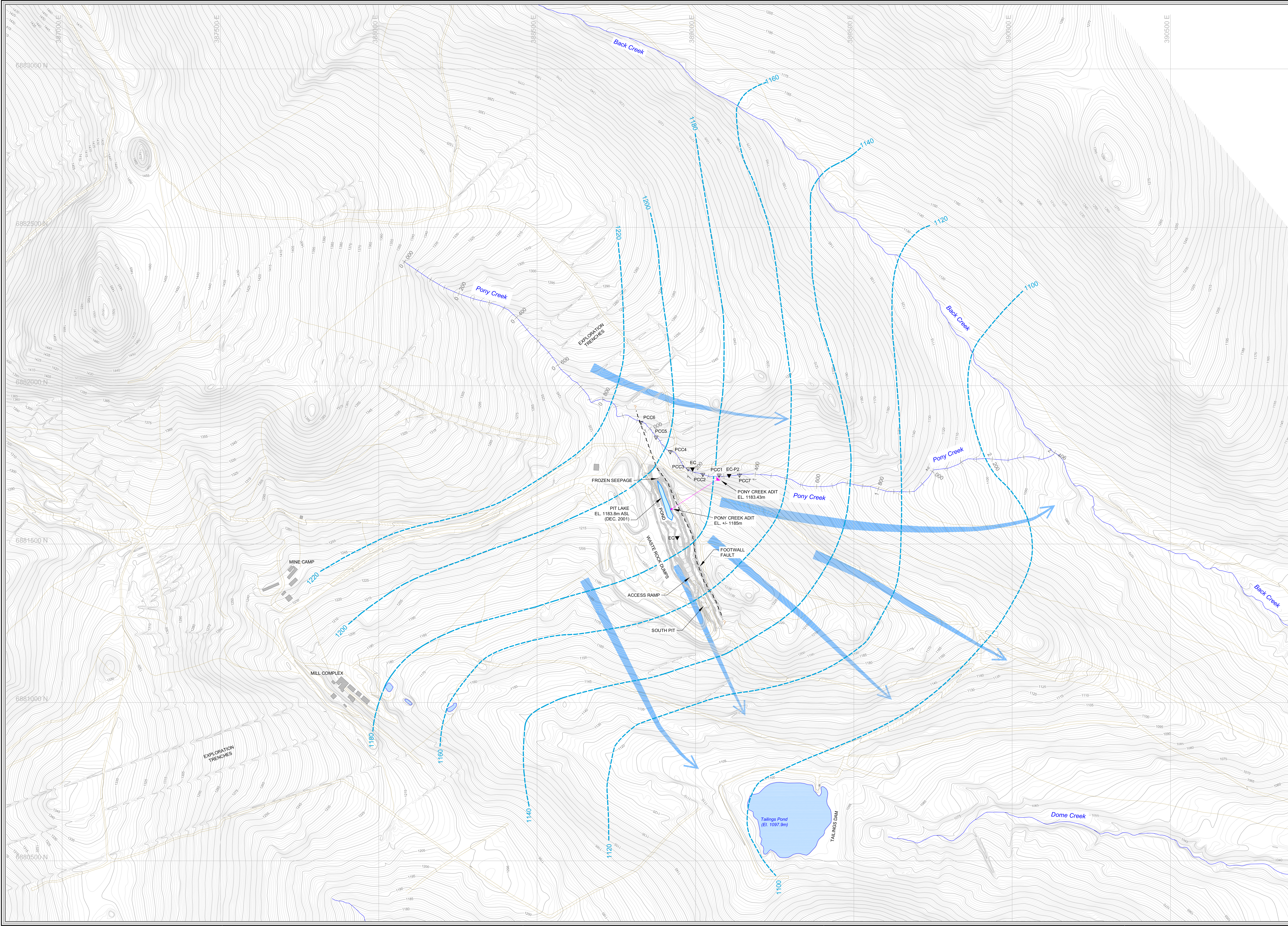
The conceptual model is provided in illustrative form in Figure 4. It should be noted, that although the Pony Creek Adit has been plugged, there remains a potential preferential flow path for pit lake water discharge through potentially fractured rock associated with the adit into Pony Creek. The Pony Creek Adit enters the Brown McDade Pit at an elevation of approximately 1,185 mASL and in the event the pit water level exceeds this elevation (which, under the proposed backfill scenario, could occur), a hydraulic gradient (i.e., driving force) through this adit, in the direction of the creek will potentially exist.

2.5.1 Hydrostratigraphic Units

Based on the available information, in general terms, the following four hydrostratigraphic units have been incorporated into the conceptual flow model. Numbers have been provided which corresponds to the Conceptual Flow Model, illustrated on Figure 4.

1. <u>Overburden (Valley bottom Aquifer System)</u>

This unit generally consists of fine to medium sand and some glacial till and forms the uppermost hydrostratigraphic unit throughout most of the study area. It is thin to non-existent on topographic (bedrock) highs and greater than 20 m thick in the bottom of the Dome Creek valley (BYG 1994). In the upper reaches of Dome Creek, the sediments are continuously frozen and therefore effectively act as a barrier to flow. In the lower reaches where the sediments are likely to be unfrozen, the sediments act as an aquifer. The hydraulic conductivity of these unfrozen overburden units is typically on the order of 10^{-4} to 10^{-6} m/sec.



Map Sources / Notes:
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Brown McDade Pit survey by Underhill Geomatics Ltd, Drawing 281-05B Dated March 18, 2003.

NTS Map Sheet 115 I / 03

1 : 5000
UTM Zone 8 N, NAD83

File Name: 70103_BY2_01_PLANMAP_SECT.DWG
Reviewed by: RM/JK Prepared by: AS/PW
Date Issued: April, 2007 Project Number: 70-103

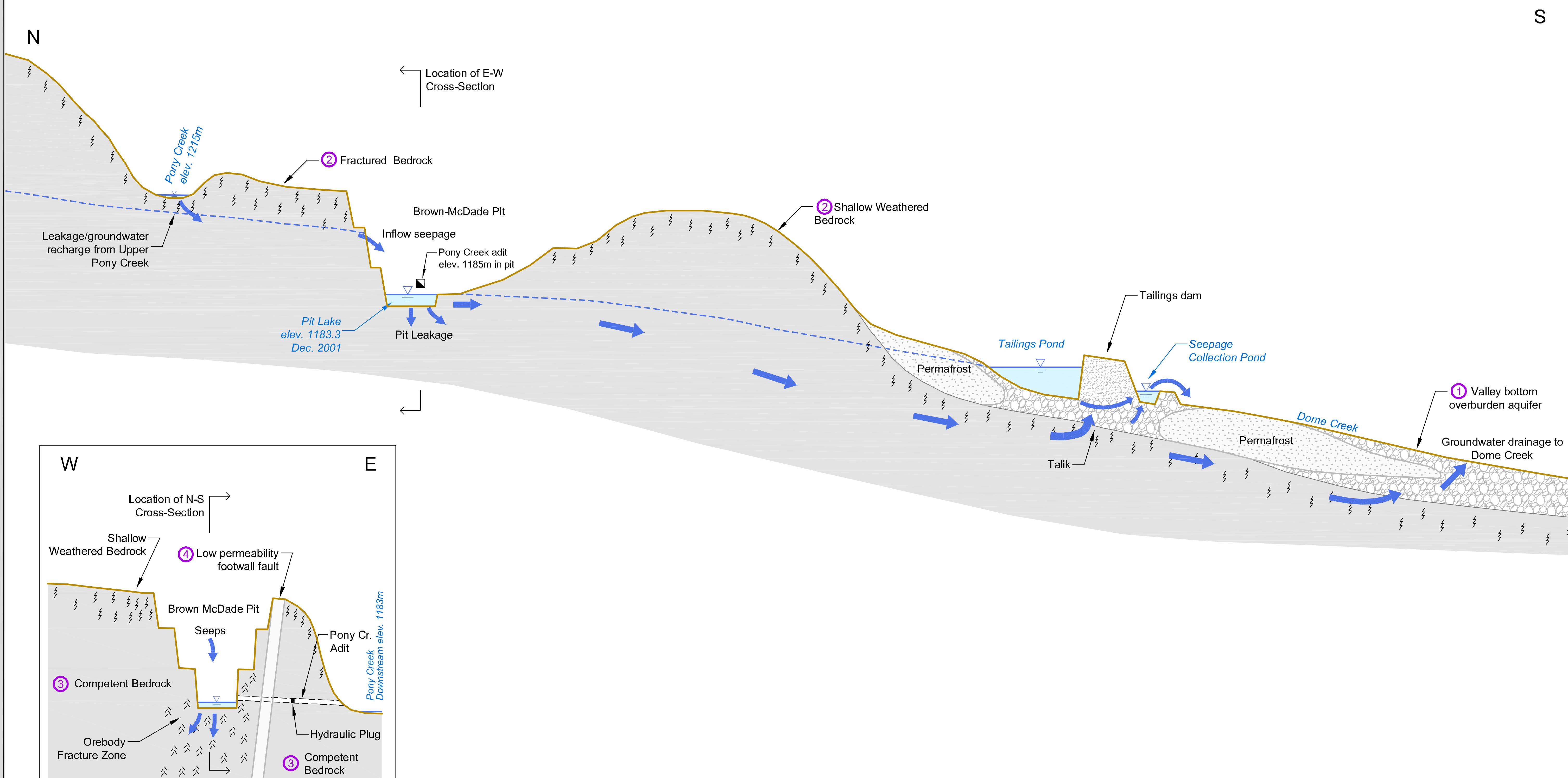
Yukon Territorial Government

Mt. Nansen Mine
Hydrogeological Conceptual Model
Location: Near Carmacks, Yukon

Interpreted Regional Groundwater Elevation Map

Gartner Lee

Figure 3
Version 1



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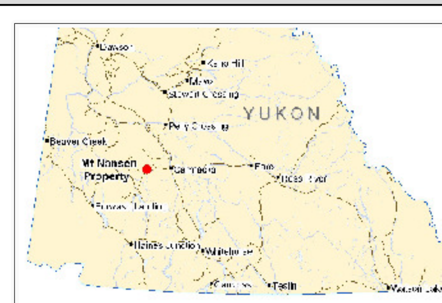
CONCEPTUAL CROSS-SECTION
NOT TO SCALE



File Name: 70103_By2_02_Brown-McDade-Section.dwg
Reviewed by: JK Prepared by: MP
Date Issued: April, 2007 Project Number: 70-103

Legend

- Ground Surface
- Water Table
- Groundwater Flow
- Surface waterbody
- Permafrost
- Bedrock
- Major bedrock fractures and frost shattering
- Minor bedrock fractures
- Alluvium
- 2 Hydrostratigraphic unit

Yukon Territorial Government

Mt. Nansen Mine
Hydrogeological Conceptual Model
Location: Near Carmacks, Yukon

Conceptual Flow Model for Brown McDade Pit

Gartner Lee

Figure 4
Version 1

Date Plotted: April 30, 2007 File Location: E:\GIS\GIS_proj\Y2007\70103 Mt Nansen\By2_HydrogeolModel_Mar07\70103_By2_02_Brown-McDade-Section.dwg

2. Shallow Fractured/Weathered Bedrock

The shallow bedrock underlying the overburden throughout most of the study area, has been affected by weathering processes such as frost-shattering and supergene oxidation. In close proximity to the Brown-McDade open pit, the thickness of the oxidized bedrock ranges from 5 m at the north end to in excess of 70 m south of the pit. In the vicinity of the pit, this unit is up to 200 m wide and hosted the ore body prior to mining. This unit is located within the fractured and brecciated zone immediately west of the Footwall Fault. The unit is inferred to extend both north and south of the pit and is inferred to intersect Pony Creek. The hydraulic conductivity of the fractured bedrock unit is estimated to be on the order of $1x10^{-3}$ to 10^{-5} m/sec.

3. Competent Bedrock

This unit encompasses the relatively competent bedrock that underlies the weathered and oxidized bedrock in the vicinity of the Brown-McDade pit. It includes relatively unfractured and unaltered granodiorite east of the footwall, as well as the adjacent metamorphic rocks. Massive competent granodiorite lies immediately east of the footwall fault, which forms the east wall and bottom of the pit. The hydraulic conductivity of this more competent bedrock is estimated to be on the order of 10^{-7} m/s.

4. Footwall Fault

The Footwall Fault forms the footwall contact between the ore and the unaltered granodiorite footwall rocks. The fault strikes 160 degrees and dips between 50 and 70 degrees to the southwest. The fault and accompanying alteration zone reportedly functioned as a barrier to groundwater inflow from the northeast pit wall during active mining (BYG 1994). No dewatering was required during mining until the pit extended to the north toward Pony Creek. The fault is inferred to extend both north and south of the pit and is inferred to intersect Pony Creek. The hydraulic conductivity of the footwall fault unit is estimated to be on the order of 10^{-7} to 10^{-9} m/s.

3. Contaminant Transport Assessment

To provide context associated with pit groundwater seepage and the potential environmental impacts it may have on nearby surface water bodies, the Conceptual Flow Model developed in Section 2 was used to provide a preliminary assessment of potential contaminant transport and dilution within the catchment.

As discussed, the complex flow interactions may effectively eliminate the ability to measure or detected point source surface water quality impacts from the pit, particularly if the relative pit water discharge represents a small percent of the overall water flowing through the system. It is for this reason, that the following assessment has been conducted so that the relative proportions of pit groundwater discharge, valley aquifer discharge and base flow discharge (on a catchment level basis), can provide a perspective on the potential for overall environmental impacts.

In the absence of detailed measured groundwater and surface water flow data, the magnitude of potential valley aquifer discharge and surface water base flow discharge in both the Dome and Victoria drainage basins, have been assumed. Using inferred valley bottom alluvial aquifer geometries (triangular), stream gradients and estimated hydraulic conductivity values (based on information provided by BYG 1994), the amount of groundwater flowing through the valley bottom aquifer systems (i.e., parallel to stream flow), was estimated using the Darcy Equation (Appendix C). The amount of groundwater flowing through the shallow Dome Creek and Victoria Creek, valley bottom alluvial aquifer system, is estimated to be on the order of 3 and 3,000 L/sec, respectively. Surface water base flow data from Dome and Victoria Creek is estimated to be 2 L/sec (per. comm., H. Copland 2006) and 50 L/sec (approximated by stream flow data provided by BYG, 1994) respectively, for a total catchment outflow discharge on the order of 5 L/sec for Dome Creek and 3000 L/sec for Victoria Creek.

To provide a rudimentary check of these estimates, the total available water in Dome and Victoria Creek catchment basins (i.e., combined as alluvial aquifer discharge and base flow discharge) was estimated using annual precipitation data and estimated infiltration rates. A mean annual precipitation rate of 211 mm/year (GLL, 2004) was applied to the catchment area with an estimated ten percent of the total precipitation reporting to the groundwater system as recharge, using a measured catchment area of 5 km^2 and 67 km^2, respectively. This calculation estimated a total catchment outflow discharge for Dome and Victoria Creek of approximately 3.5 and 4,700 L/sec respectively, which are constant with the approximations made above. It is important to note, that the calculations represent minimum discharge rates, and do not account for much larger volumes of water expected to pass through the drainage system during unfrozen periods.

Based on the estimated groundwater seepage rate out of the Brown McDade pit (0.2 L/sec, GLL 2005) compared to the calculated basin aquifer discharge and surface base flow discharge (i.e., 5 L/sec for Dome Creek and 3,000 L/sec for Victoria Creek), it is estimated that dilution factors of approximately 25 times (within Dome Creek catchment) and 16,000 times (within Victoria Creek catchment) are potentially available.

Zinc concentrations in the Brown McDade pit have previously been observed to fluctuate between 0.5 mg/L and 3 mg/L. The Canadian Council for Ministers of the Environment (CCME) guideline for the protection of aquatic life for zinc is 0.030 mg/L. As such, a dilution factor of at least 100 times is required to meet the CCME guideline at the discharge point, assuming that there are no chemical or physical reactions occurring within the groundwater flow system to attenuate contaminant concentrations. Although attenuation processes have not been the focus of this study, it is anticipated that natural attenuation processes in the groundwater flow system would likely provide a reduction in dissolved metal concentration along the groundwater flow path. Given the identified presence of organic rich sediments with the lower valley bottom aquifer system (BYG 1994), significant metal attenuation potential may exist, particularly within the unfrozen unconsolidated valley bottom aquifer system.

Based on the calculations and estimates provided, zinc concentrations originating from the pit are anticipated to have negligible impact on surface water quality in Victoria Creek, and may have only minor impacts on water quality in Dome Creek, under baseflow (i.e., worst case) conditions. As discussed, these approximations are conservative. In fact, water quality monitoring in Dome Creek (below the tailings dam), throughout the 2006/2007-baseflow season has met applicable discharge criteria.

During much of the year (May to October), stream flows will be much higher due to surface runoff and consequently more dilution potential than was calculated in this desktop study will be available in the streams to reduce potential contaminant concentrations. It is anticipated that while there is likely very little mixing (i.e., dispersion or a reduction in concentration) in the groundwater flow system, it is anticipated that advective and dispersive process, particularly within the interface between the alluvial groundwater and surface water systems, will occur. This process will likely provide a reduction in concentration that will inhibit the ability to detect the point source impact associated with pit water seepage and discharge to the surface water environment.

Groundwater travel time calculations were also performed using the Darcy Equation (Appendix C) using the interpreted groundwater flow map provided in Figure 3. The interpreted groundwater flow paths originating in the vicinity of the Brown-McDade pit and ending in the Dome Creek valley aquifer were used to approximate travel distances. This information was then combined with the interpreted groundwater elevations (i.e., gradients) outlined in Figure 3 and was used to estimate the groundwater travel times. In all cases a porosity of 1% was assumed based on typical literature values for fractured crystalline and metamorphic rock (Freeze and Cherry, 1979). Using a saturated bedrock hydraulic conductivity of 1×10^{-7} m/s, it is estimated that groundwater seepage originating from the open pit would take approximately 19 years to reach the Dome Creek Valley bottom aquifer. With an order of magnitude increase in hydraulic conductivity or an order of magnitude decrease in porosity, the travel times would be shortened to 2 years.

Based on the interpreted flow system and conceptual flow model, seepage originating from the Brown-McDade pit is unlikely to impact the artesian water supply well. However, groundwater travel times were estimated to provide approximate time frames for arrival of pit seepage water should groundwater gradients and flow directions permit. These calculations applied an estimated groundwater travel distance of 2.2 km, a hydraulic conductivity of 1×10^{-7} m/s and a porosity of 1%. Based on these assumptions, seepage water originating from the open pit could potentially take 100 years to reach the artesian supply well. Given this lengthy travel time and distance, the relatively low flow component of seepage water flowing through the system, and the low likelihood of seepage reporting directly to the artesian well supply, water quality in the artesian well is not considered at risk of being contaminated by pit seepage groundwater.

4. Assessment of Pit Backfilling

The project scope of work included a request to comment on the potential implications of using benign waste rock to partially backfill the Brown-McDade pit. For the purposes of this assessment, we have assumed that the infill material will not alter the chemistry of the pit lake and will not affect the observed pit water chemistry. This assumption is likely conservative (i.e., worse case), as it would be expected that the current situation (i.e., direct exposure of un-oxidized mineralization at the bottom of the pit to shallow surface water exposed to the open air) is likely producing a worst case dissolved metal concentration. It is also assumed that the pit will not be filled to a level above the north wall seepage face and therefore no change in seepage water inputs would be expected. Additionally, it is anticipated that the waste rock material to be in filled, will have a higher hydraulic conductivity than the pit bottom bedrock, and therefore no change in seepage rate out of the pit bottom would be expected.

Given the assumptions listed, the impacts of partially backfilling the pit, will primarily result in an overall change in pit storage capacity. The amount of waste rock to be placed in the pit is estimated to fill the pit to the current water level, which is approximately 1,183 mASL (per. comm., H. Copland, 2007). Additionally, based on the subsequent calculations, it is anticipated that the resulting pit water level will be greater than 1,183 mASL, and therefore the pit will still lose water through evaporation.

Since the last dewatering event was conducted in 2004, end of winter pit water levels have increased year after year. Water levels between January 2006 and June 2006 were between 1,181.7 and 1,182.4 mASL, respectively. These observation suggest that the Brown-McDade pit is still filling and has not yet reached the so-called “equilibrium elevation” where total annual inputs equal total annual outputs. This trend is consistent with earlier “final pit water elevation” predictions that estimated the steady state “open pit” water level would be approximately 1,184.9 mASL or 1,185 mASL (GLL, 2004). A confirmation of this estimate has not yet been conducted and should be completed as soon as possible in order to validate the modelling results (i.e., the pit should be left to fill and monitored on a routine basis).

Assuming that the predicted “open pit” water level elevation (1,185 mASL) will occur, the change in storage as a result of back filling to an elevation of 1,183 mASL has been calculated. Assuming a 30% porosity of the waste rock (which is reasonable given the fine grain nature of the material), the final pit water elevation is estimated to be 1,185.5 mASL. This marginal increase in the predicted pit water elevation is due to the fact that the “Pit Water Elevation versus Pit Volume” curve is an exponential function (GLL 2004).

Based on the assumptions provided above, the benefits of infilling the pit to the suggested elevation of 1,183 mASL may provide a number of modest benefits which include:

1. An added reduction in the direct exposure of oxygenated water to the un-oxidized ore body located at the pit bottom, thereby potentially improving pit seepage water quality under the pit. Specifically the potential for adverse chemical effects of a pit surface water inversion or "turnover", (GLL 2005), would likely be diminished.
2. The proposed volume of back fill will allow for pit water losses to remain active (i.e., evaporation will occur during summer months) and therefore significant changes to fluctuations in the observed pit water elevation or final predicted pit water elevation, will likely not be significantly affected.
3. The depth of water within the pit will be reduced therefore reducing the potential for accidental injury.

As discussed in Section 1.2, the focus of the Conceptual Model is to assess the fate of poor water quality leaving the Brown McDade pit. This work will create a framework and rational for future site characterization and ultimately site closure recommendations. By providing a better understanding of the pit flow regime it is anticipated that the recommendations of this report will be coupled with site-specific geochemical information (i.e., the potential geochemical implications of a change in the pit flow regime must be assessed to ensure the changes do not create a worse condition than present).

5. Summary of Conclusions

The following provides a summary of the pertinent conclusions:

1. Based on the information provided in this report, it is likely that seepage leaving the Brown McDade Pit reports to a bedrock aquifer system, which eventually recharges down valley and discharges to a talik under the tailings pond and or to the unconsolidated valley bottom aquifer system, located most likely in the Dome Creek drainage basin (Figure 3).
2. It is very difficult to assess and or locate specifically where the groundwater flow lines leaving the Brown McDade pit will inevitably discharge from the bedrock aquifer into the valley bottom aquifer, and potentially daylight into the surface water system, particularly given the complexity associated with bedrock groundwater flow and groundwater/surface water flow interactions. It is likely that the flow hydraulics associated with these processes will effectively eliminate the ability to measure or detect a surface water quality impact from the point contaminant source, particularly when the relative pit water seepage represents only a small percentage of the overall water flowing through the system.

3. Discharge from the Brown McDade pit is part of a large scale groundwater and surface water flow system and therefore impacts to the environment have been assessed based on a "catchment level" basis. The calculations represent minimum discharge rates, and do not account for much larger volumes of water expected to pass through the drainage system during unfrozen periods. Therefore, the dilution calculations provided are considered to be a conservative estimate. Based on the measured groundwater seepage rate out of the Brown McDade pit (0.2 L/sec, GLL 2005) compared to the estimated basin aquifer discharge and surface base flow discharge (i.e., 5 L/sec for Dome Creek and 3,250 L/sec for Victoria Creek catchment basins), dilution factors of approximately 25 times (for Dome Creek catchment) and 16,000 times (for Victoria Creek catchment) are potentially available.

4. On an annual basis it is estimated the Pony Creek seepage component represents approximately 75% to 80% of the total water reporting the pit (calculated from GLL 2005, Pit Water Balance). A reduction in seepage flow into the pit will likely have a dramatic effect on reducing the volume of subsequent discharge out of the pit to the underlying bedrock aquifer system. However the effect on pit seepage water quality should be considered prior to implementing a change in the current pit water flow regime.

5. Assuming that the predicted "open pit" water level elevation (1,185 mASL) will occur, the change in storage as a result of back filling to an elevation of 1,183 mASL has been calculated. The final pit water elevation is estimated to be approximately 1,185.5 mASL (only marginally higher than the estimated "open pit" lake elevation 1,185 mASL, GLL 2005). Based on the assumptions outlined, the benefits of infilling the pit to the suggested elevation of 1,183 mASL may provide a number of modest benefits which include:

    a) An added reduction in the direct exposure of oxygenated water to the un-oxidized ore body located at the pit bottom, which may potentially improve pit seepage water quality.

    b) Assuming no changes in water "in-puts" occur, the proposed volume of pit back fill will likely permit water losses to remain active (i.e., evaporation will still occur during summer months), and therefore significant changes to fluctuations in the observed pit water elevation or final predicted pit water elevation, will likely be minimal.

    c) The pit water depth will not be as deep and will therefore help reduce the potential for accidental injury.

6. It is recognized that although the Pony Creek Adit has been plugged, there remains a potential preferential flow path for pit lake water discharge through

the bedrock vicinity of the adit, into Pony Creek. The Pony Creek Adit enters the Brown McDade Pit at an elevation of approximately 1,185 mASL and in the event the pit water level exceeds this elevation (which, under the proposed backfill scenario, will likely occur), a hydraulic gradient (i.e., driving force) through this adit, in the direction of the creek will potentially be created.

6. Recommendations

The following provides a summary of the pertinent recommendations:

1. It should be recognized that potential geochemical implications of implementing a change in the pit flow regime must be assessed to ensure the change does not create a worse condition than currently exists.
2. Steady state pit water elevation is estimated at approximately 1,185 mASL. A confirmation of this prediction has not yet been conducted and should be completed as soon as possible in order to validate the modelling results (i.e., the pit should be left to fill and monitored on a routine basis).
3. The surface water drainage course along Pony Creek, in the vicinity of the Brown McDade pit, could be restored (i.e., exploration berms removed – location shown on Figure 1) in an attempt to minimize ponding and enhance surface water flow through this reach of the creek and to potentially reduce groundwater recharge in this area and subsequent seepage into the north end of the pit. To assess the effectiveness of this procedure seepage monitoring into the pit should be conducted in conjunction with pit water level monitoring.
4. Following the effectiveness of improving surface drainage along Pony Creek, it is recommended that a shallow bedrock well be completed in the low permeable bedrock north of the pit, (i.e., on the west side of the foot wall fault) to assess the potential of dewatering this zone, again to reduce pit inflow (i.e., capture shallow subsurface bedrock flow before it enters the pit). This test will also help assess the potential effectiveness of a grout curtain or seepage cut off wall, which would provide a similar function.
5. In order to help confirm groundwater gradients and flow directions in the deeper competent bedrock aquifer system, it is recommended that a shallow bedrock well be installed between the north and south pit. Additional benefit could be provided with a third well at the end of the Pony Creek Adit. Collectively, the water level information from these wells will provide further evidence to support or refute the Conceptual Flow Model outlined in this study.

7. Limitations

This report was prepared for the exclusive use of Yukon Government, Energy, Mines and Resources. The report, which specifically includes all tables and figures, is based on data and information collected during the investigations conducted by Gartner Lee Limited, and is based solely on the conditions of the site at the time of the investigation, supplemented by historical information and data obtained by Gartner Lee Limited, as described in this report.

The investigations and designs described in this report were conducted in a manner consistent with that level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

Any use which a third party makes of this report, or any reliance on, or decisions to be made based on it, are the responsibility of such third parties. Gartner Lee Limited accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on the information contained in this report.

Should you have any questions regarding this report, or require further information, please contact the undersigned.

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Appendix A

February 2007 Site Photos

- PHOTOGRAPHS -

PHOTOGRAPH 1

Large icing and evidence of exfiltration from pit bottom. Broken ice can be seen in the forground. Facing north.

PHOTOGRAPH 2

Dome Creek valley from mill site. Facing east.

- PHOTOGRAPHS -

PHOTOGRAPH 3

Brown-McDade open pit (left) and Pony Creek valley (right). Taken from road facing west.

Appendix B

Water Quality Data

Project	**Mt. Nansen Water Analysis**
Report to	**Government of Yukon - EMR**
ALS File No.	**Z5093**
Date Received	**10/27/2006**
Date:	**11/22/2006**

RESULTS OF ANALYSIS

Sample ID	**CDWQG**	**CCME**	POND	SEEP	UPPER DOME	DOME @ ROAD	UPPER VICTORIA	VICTORIA @ ROAD	WELL
Date Sampled			10/26/2006	10/26/2006	10/26/2006	10/26/2006	10/26/2006	10/26/2006	10/26/2006
Time Sampled									
ALS Sample ID			2	1	3	5	4	6	7
Nature			Water	Water	Water	Water	Water	Water	Water
Physical Tests									
Conductivity (uS/cm)			2100	1820	1580	1370	218	243	325
pH	6.5-8.5		7.91	7.71	7.88	7.86	7.94	7.97	8.10
Dissolved Anions									
Alkalinity-Total CaCO3			148	207	205	194	107	113	163
Alkalinity-Bicarbonate CaCO3			148	207	205	194	107	113	163
Alkalinity-Carbonate CaCO3			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Alkalinity-Hydroxide CaCO3			<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
Sulphate SO4	<500		1050	824	695	582	21.8	39.8	23.3
Nutrients									
Ammonia Nitrogen N			2.97	9.36	6.69	4.50	0.028	0.053	0.023
Nitrate Nitrogen N	45 or 10		3.30	5.45	3.96	2.60	0.0660	0.166	0.106
Nitrite Nitrogen N	3.2		0.115	0.196	0.106	0.0625	<0.0010	<0.0010	<0.0010
Cyanides									
Total Cyanide CN	0.2		0.0184	0.0435	0.0252	0.0214	0.0057	0.0065	-
Cyanate CNO			<0.50	<0.50	<0.50	0.57	<0.50	<0.50	-
Thiocyanate SCN			1.76	7.91	3.54	1.91	<0.50	<0.50	-
WAD Cyanide CN			0.0086	0.0406	0.0233	0.0112	<0.0050	<0.0050	-
Total Metals									
Aluminum T-Al			<0.20	<0.20	<0.20	<0.20	0.32	<0.20	<0.20
Antimony T-Sb	0.006		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic T-As	0.025		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Barium T-Ba	1		0.025	0.052	0.052	0.064	0.094	0.075	0.080
Beryllium T-Be			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth T-Bi			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Boron T-B	5		0.18	0.11	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium T-Cd	0.005		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium T-Ca			300	265	217	188	28.7	30.2	37.1
Chromium T-Cr	0.05		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt T-Co			<0.010	0.016	0.011	<0.010	<0.010	<0.010	<0.010
Copper T-Cu	<1		0.055	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron T-Fe	<0.3		0.699	11.4	4.78	1.78	0.560	0.192	0.411
Lead T-Pb	0.01		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium T-Li			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium T-Mg			45.5	31.2	35.4	37.3	9.98	10.4	18.1
Manganese T-Mn	<0.05		1.69	7.85	5.15	3.59	0.108	0.0831	<0.0050
Molybdenum T-Mo			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel T-Ni			<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus T-P			<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium T-K			16.7	7.4	5.6	4.9	<2.0	<2.0	<2.0
Selenium T-Se	0.01		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon T-Si			3.28	5.94	5.22	5.93	6.11	6.11	5.41
Silver T-Ag			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium T-Na	<200		126	108	75.0	57.1	2.5	4.6	4.1
Strontium T-Sr			0.745	0.688	0.592	0.514	0.282	0.261	0.546
Thallium T-Tl			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin T-Sn			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium T-Ti			<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium T-V			<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc T-Zn	<5.0		0.0607	0.0098	0.0094	0.0130	<0.0050	<0.0050	<0.0050
Dissolved Metals									
Aluminum D-Al			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Antimony D-Sb	0.006		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Arsenic D-As	0.025		0.0303	0.0021	0.0044	0.0051	0.00070	0.00199	0.00059
Barium D-Ba	1		0.021	0.045	0.049	0.063	0.083	0.074	0.076
Beryllium D-Be			<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050	<0.0050
Bismuth D-Bi			<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20

Boron D-B	5	0.17	0.10	<0.10	<0.10	<0.10	<0.10	<0.10
Cadmium D-Cd	0.005	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Calcium D-Ca		287	255	219	192	27.7	29.4	35.7
Chromium D-Cr	0.05	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Cobalt D-Co		<0.010	0.014	0.010	<0.010	<0.010	<0.010	<0.010
Copper D-Cu	<1	0.038	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Iron D-Fe	<0.3	<0.030	0.055	<0.030	0.087	<0.030	0.090	<0.030
Lead D-Pb	0.01	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Lithium D-Li		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Magnesium D-Mg		41.3	31.5	35.8	37.8	9.64	10.1	17.4
Manganese D-Mn	<0.05	1.57	7.23	5.07	3.64	<0.0050	0.0776	<0.0050
Molybdenum D-Mo		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Nickel D-Ni		<0.050	<0.050	<0.050	<0.050	<0.050	<0.050	<0.050
Phosphorus D-P		<0.30	<0.30	<0.30	<0.30	<0.30	<0.30	<0.30
Potassium D-K		15.1	7.5	5.9	5.1	<2.0	<2.0	<2.0
Selenium D-Se	0.01	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Silicon D-Si		2.88	5.28	4.98	5.97	5.45	5.90	5.27
Silver D-Ag		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Sodium D-Na	<200	114	111	76.3	58.0	2.4	4.4	4.1
Strontium D-Sr		0.675	0.697	0.601	0.525	0.271	0.253	0.525
Thallium D-Tl		<0.20	<0.20	<0.20	<0.20	<0.20	<0.20	<0.20
Tin D-Sn		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Titanium D-Ti		<0.010	<0.010	<0.010	<0.010	<0.010	<0.010	<0.010
Vanadium D-V		<0.030	<0.030	<0.030	<0.030	<0.030	<0.030	<0.030
Zinc D-Zn	<5.0	0.0390	<0.0050	<0.0050	0.0090	<0.0050	<0.0050	<0.0050
Bioassays (a,b)								
LT-50		-	>96	-	-	-	-	-

Footnotes:

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.
(a) Bioassays analysis was subcontracted to Golder Associates in North Vancouver
(b) Refer to the appendix for detail.

Appendix C

Darcy Equation

The groundwater travel times were approximated using the Darcy Equation, shown as follows:

$$\frac{Q}{A} = q = K_s x \frac{dh}{dl}$$

$$\bar{v} = \frac{q}{\eta}$$

$$t = \frac{dl}{\bar{v}}$$

where:	Q	is the volumetric discharge [m^3/s]
	A	is the cross-sectional area [m^2]
	q	is the Darcy flux [m/s]
	K_s	is hydraulic conductivity of the medium
	dh	is the change in groundwater head (hydraulic potential)
	dl	is the horizontal distance associated with dh
	$\bar{v}$	is the average porewater velocity
	η	is the average porosity of the medium
	t	is the travel time between the endpoints of dh