Gartner Lee

# Preliminary Groundwater Assessment of the Proposed Whitehorse Copper & Mount Sima Development Area

*Prepared for*

**Community Development Branch**
**Government of Yukon**

*Prepared by:*

**Gartner Lee Limited**

*GLL 22-586*

*December 2002*

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December 4, 2002 GLL 22-586

Community Development Branch
Government of Yukon
Box 2703
Whitehorse, Yukon
Y1A 2C6

Attn: Brian Ritchie, Manager, Land Development

Dear Mr. Ritchie:

Re: Preliminary Groundwater Assessment of the Proposed Whitehorse Copper & Mount Sima Development Area

Gartner Lee Limited is pleased to provide our final report on the above noted project. We trust that this assessment meets your current needs. If we can be of any further assistance, please do no not hesitate to contact the undersigned at 633-6474 extension 23.

Yours very truly
GARTNER LEE LIMITED

Forest Pearson,
Engineering Geologist, B.Sc.

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# Executive Summary

The Community Development Branch of the Government of Yukon is currently preparing a Development Plan for the Whitehorse Copper area. The Development Plan, which encompasses a 20 $km^2$ area located in the south-western portion of the City, has a provision for 156 rural residential lots and 62 service (light) industry lots. Lots will not be serviced by municipal sewer or water, and property owners will be responsible for provision of such services. In response to the proposed development plan, neighboring residents in the Wolf Creek and Pineridge subdivisions have expressed some concerns regarding potential impacts to groundwater. This report assesses the potential impacts to local groundwater resources arising from the proposed development.

The following study components have been completed for the purpose of completing the assessment:

1. Overview of the local hydrogeological regime based on previously published data;
2. Groundwater balance calculated for the development area using available terrain data and Environment Canada water surplus estimates for the Whitehorse area;
3. Predict bulk nitrate concentrations in groundwater resulting from proposed development and from existing Wolf Creek development, using best available ("order-of-magnitude") methodology.
4. Predicted groundwater nitrate concentrations compared to available groundwater quality data in Wolf Creek subdivision.

The following conclusions have been drawn from the analysis completed:

- Most new wells in the proposed developments will likely be completed in bedrock.

- Over half of the proposed development area is likely to be underlain by granodiorite bedrock. Historically, development of private wells in this rock type has proven to be difficult, expensive or unsuccessful. Trucked water delivery may be a more viable alternative for homes in areas underlain by granodiorite bedrock.

- The estimated annual groundwater recharge rate exceeds the estimated groundwater consumption rate, indicating that development of the proposed subdivision is unlikely to deplete groundwater resources in the area.

- Only a small portion of the proposed development is hydraulically up-gradient from the existing country residential subdivisions of Wolf Creek and Pineridge. Most of the wells and septic fields that will be installed in the proposed development are expected to have no effect on existing groundwater users in Wolf Creek and Pineridge areas.

- The modelled nitrate concentrations in the Whitehorse Copper area following development are lower than the modelled concentrations in groundwater from the Wolf Creek subdivision under current conditions. The model concentrations for the existing Wolf Creek Subdivision are in turn higher than the actual measured concentrations. Furthermore, recently measured concentrations of nitrate in groundwater samples from the Wolf Creek subdivision met Canadian Drinking Water Quality Guidelines with a few exceptions. These results indicate that nitrate introduced to groundwater from septic loading in the Whitehorse Copper development area are unlikely to pose health concerns to groundwater users in the area. However, it is recommended that routine monitoring of groundwater quality from the Whitehorse Copper area be conducted as the development proceeds.

# 1. Introduction

## 1.1 Background

The Whitehorse Copper Area Development Scheme was approved by the City of Whitehorse City Council in November 1999. The scheme provides the framework for the development of a 20 $km^2$ area located in the southwestern portion of the City Whitehorse. The area is 10 km south of the downtown core along the Alaska Highway. The Wolf Creek and Pineridge rural residential subdivisions are south of the proposed development area (Figure 1).

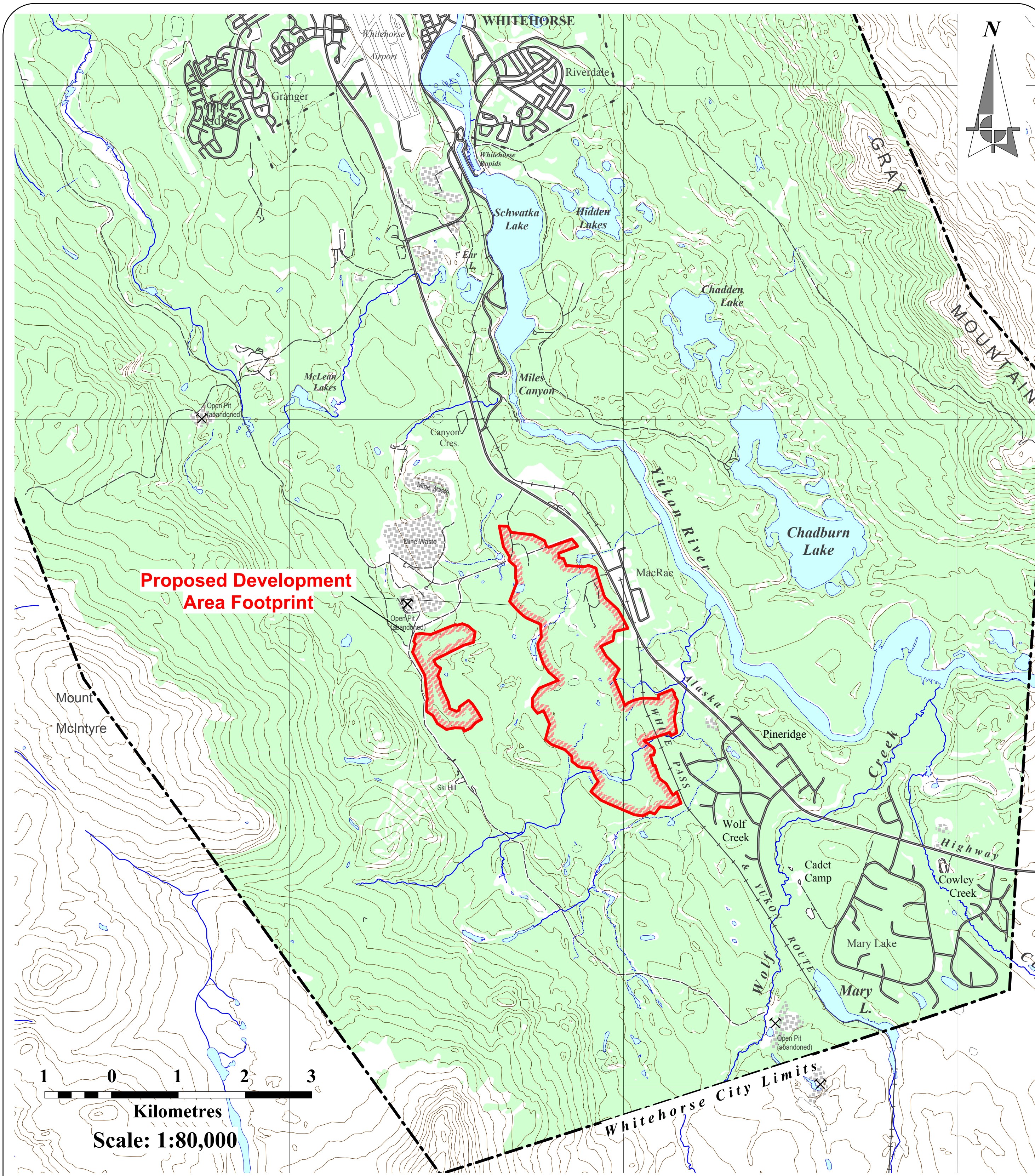
The Community Development Branch of the Government of Yukon is currently preparing a Development Plan for the area. The Development Plan is expected to provide for 156 rural residential lots and 62 service (light) industry lots. The average rural residential lot size are proposed to be 1.37 ha each. Lot density over the study area footprint (including roadways and minor greenbelts) is expected to be 0.42 lots per hectare. The proposed development layout is shown on Figure 2. Lots will not be serviced by municipal sewer or water, and property owners will be responsible for provision of such services. This rural residential style of development is common in the City of Whitehorse. Historically, there has been a significant demand for this type of development

## 1.2 Scope of Work and Methodology

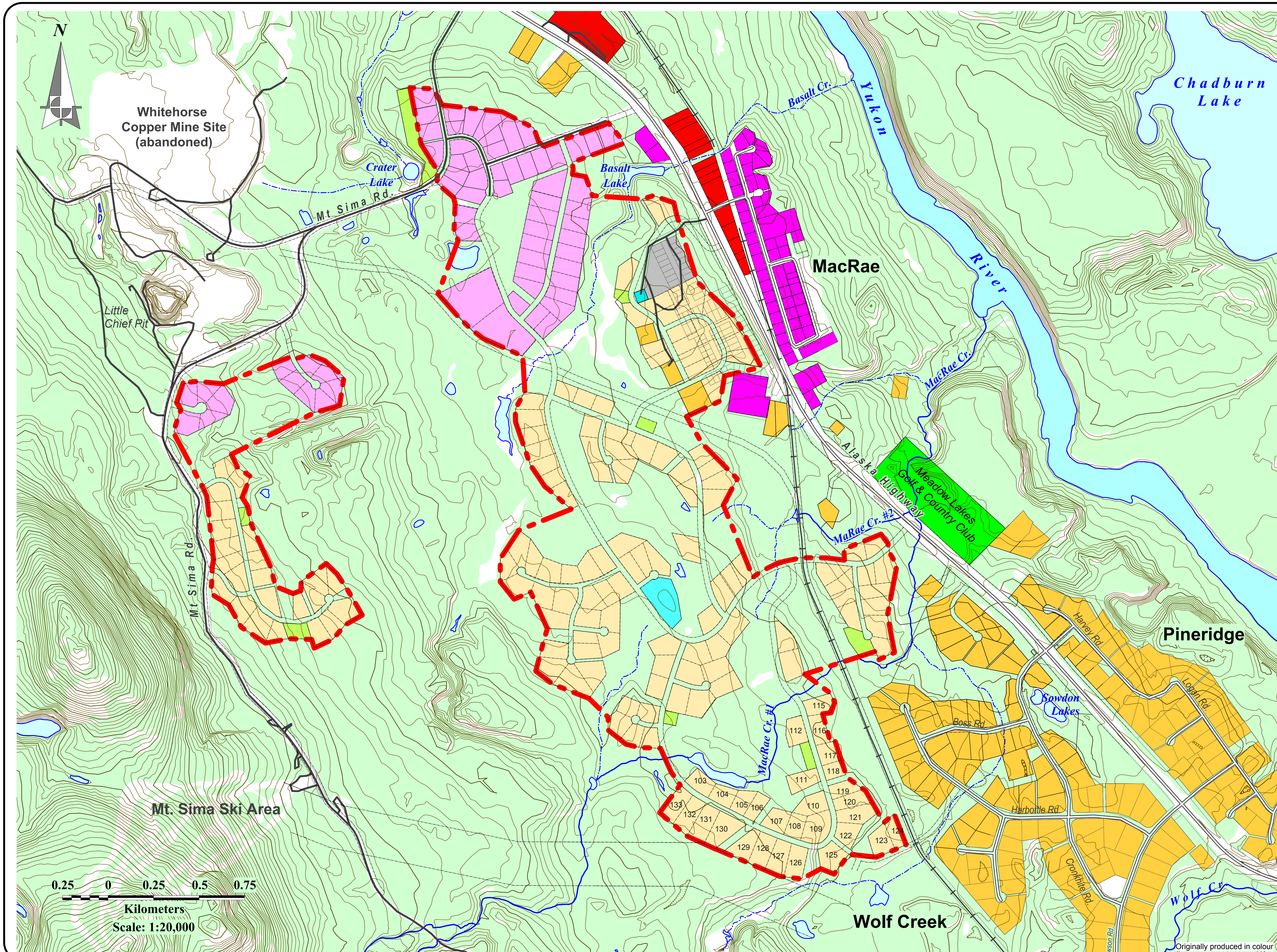
The purpose of this report is to provide an assessment of the potential impacts to local groundwater conditions from the Whitehorse Copper development. Specific objectives include:

1. Providing an overview of the local hydrogeological regime;
2. Calculating a groundwater balance to estimate potential impacts on the local groundwater system from the proposed developments; and
3. Undertaking an aquifer sensitivity analysis to help assess the potential for nitrate contamination of groundwater from existing and proposed septic effluent loading.

A brief description of the methodology and information sources used to address each of the study components is provided in the following sections.




| | | |
|---|---|---|
| Site Name: Whitehorse Copper<br>File Name: 22586-F1.WOR<br>Gartner Lee Limited<br>Scale: 1:80,000 | **Community Development Branch**<br>**Government of Yukon**<br>**PRELIMINARY GROUNDWATER ASSESSMENT**<br>**WHITEHORSE COPPER DEVELOPMENT AREA**<br>**Project Location Map** | Project No: 22586<br>Date Issued: Oct. 2002<br>**Figure 1** |




LEGEND:

Proposed Development Area Footprint

PROPOSED LAND USE

- Country Residetial
- Service Industry
- Parks
- School Site

EXISTING LAND USE

- Land Claims
- Commerical
- Country Residential
- Heavy Industry
- Parks & Recreation
- Public Utilities

Source of Basemap:
City of Whitehorse 1:20,000 topographic base. 1996. Triathlon Mapping Corp.

Subdivison Plan:
Inukshuk Planning & Development, 2002.

Reviewed By: FKP

Drawn By: FKP

Date Issued: Nov. 2002

Project Number: 22-586

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Revision: 1

**Proposed Subdivision Layout**

**Preliminary Groundwater Assessment**
**Whitehorse Copper Development Area**
**Community Development Branch, YTG**

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Figure No. **2**

### 1.2.1 Overview of Local Hydrogeological Regime

Understanding the characteristics of the local groundwater resource is critical to determining the potential for impacts. The current study relies on previously published information to characterize the hydrogeological regime. The following information sources have been utilized in the assessment:

- 1:15,000 scale terrain map of development area (EBA Engineering Consultants Ltd. 2002);
- 6 Monitoring wells along Mt. Sima access road installed in 1991 (Piteau Engineering 1991a,b);
- Approximate groundwater surface elevations from private Wolf Creek subdivision wells (Gartner Lee Limited 2001a,b);
- Well construction information in Wolf Creek/Pineridge subdivisions (Gartner Lee Limited 2001a);
- Regional scale (1:50,000) bedrock geological mapping (Gartner Lee Limited 2002)

### 1.2.2 Groundwater Balance for Development Area

A groundwater balance has been completed incorporating precipitation recharge and groundwater consumption. The precipitation recharge is calculated using a methodology incorporating available precipitation for recharge (water surplus) and the following infiltration factors: topography, soil, and cover type. The water surplus was previously calculated for the Whitehorse area by Environment Canada (Gartner Lee Limited 2001b). Topography and land cover information was obtained from 1:20,000 City of Whitehorse topographic mapping (Triathlon Mapping Corp., 1996). Local soils information was derived from work by EBA Engineering Consultants Ltd. (2002), and Mougeot Geoanalysis (1996).

Groundwater demand and consumption predictions are based on best available estimates for number of lots, expected per capita use (including lawn watering), and evapotranspiration losses.

### 1.2.3 Aquifer Sensitivity Analysis

Septic disposal system discharges have the potential to affect local groundwater resources. Common potential contaminants include bacteria, viruses, and nitrates. Generally, natural attenuation processes within the ground eliminate and/or mitigate the potential impacts from these contaminant sources. Most soils are particularly effective at impeding the migration of bacteria and viruses. In addition, the organisms are generally not viable in soil/groundwater and die-off occurs relatively rapidly. Nitrates are relatively more mobile although attenuation processes (ie. dilution, denitrification, etc.) do occur in the subsurface.

This study has examined the potential impacts resulting from septic loading of nitrates to groundwater. A very conservative assessment methodology has been used (Ontario Ministry of Environment 1995) using best available local information. The methodology uses typical nitrate loadings from individual septic system use and allows for dilution with infiltrating precipitation *from the development footprint only*. The resulting prediction likely over-predicts actual nitrate concentrations since it does not consider the conversion of nitrates to nitrogen gas (denitrification) or the dilution available from mixing with groundwater originating upgradient of the development area. Despite these limitations, the methodology provides a reasonable "order-of-magnitude" assessment and provides a tool for comparing the proposed Whitehorse Copper development with existing conditions in the Wolf Creek and Pineridge subdivisions. Actual groundwater quality data collected from the Wolf Creek and Pineridge subdivisions (Gartner Lee Limited 2002a) have been used to provide context for the modelled nitrate concentrations.

# 2. Hydrogeological Setting

The proposed development is located on the Upland Benches landscape setting of Whitehorse (Gartner Lee Limited 2002c). This landscape setting is characterized by rolling topography that is frequently dissected by glacial meltwater channels and smaller stream channels. Elevations in the proposed development area rise from 730 m above mean sea level (ASL) in the east to 870 m ASL in the west.

The study area for the development (Figure 1) is bounded by the :

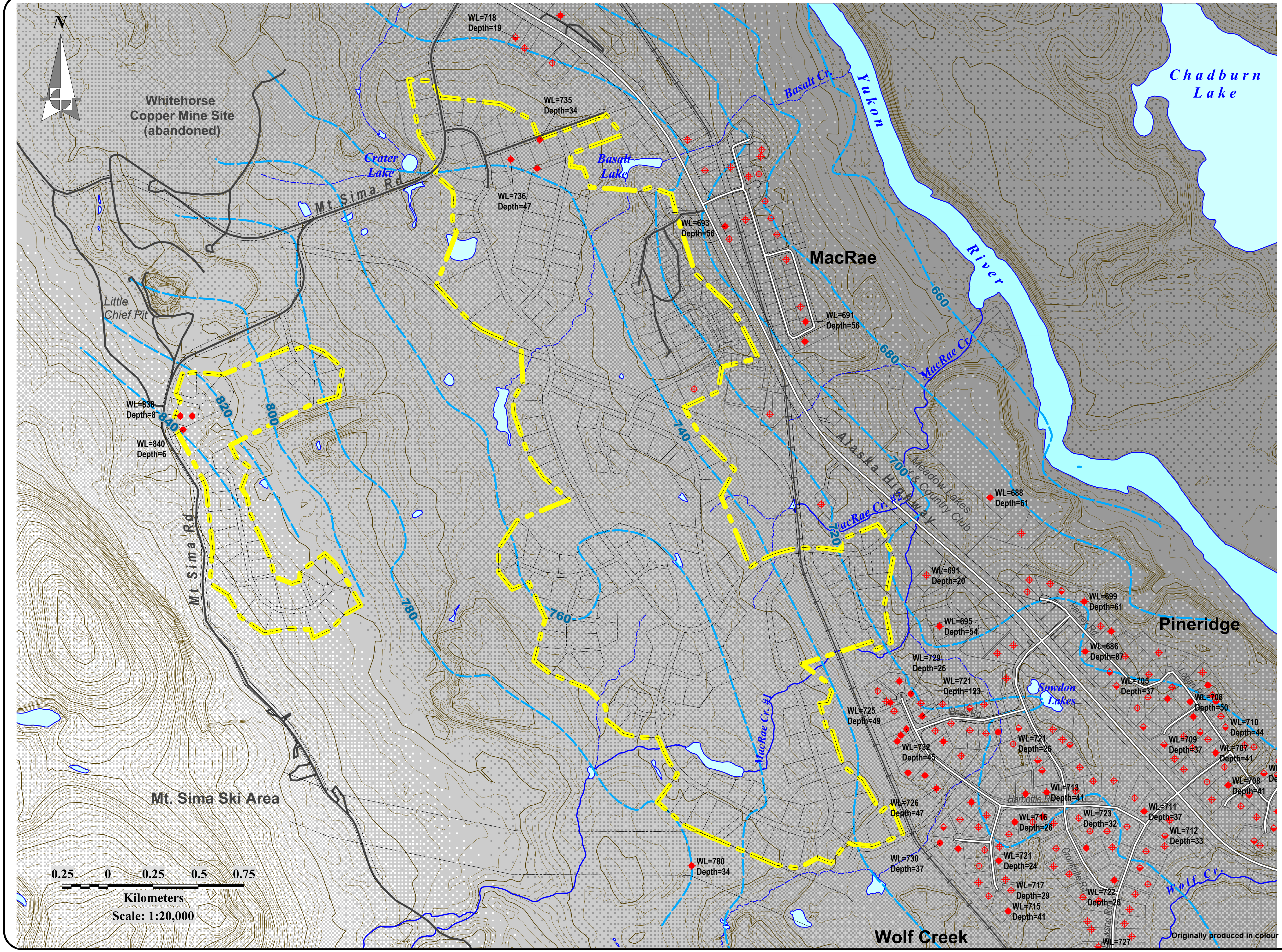
- Alaska Highway to the east;
- Mount Sima road (formerly the Copper Haul Road) to the west;
- former Whitehorse Copper mine site to the north; and
- Wolf Creek subdivision to the south.

Surficial materials within the study area include glacial till, till veneers, glaciofluvial sand and gravel, near surface bedrock or bedrock outcrops and some isolated areas of organic veneers (wetlands). A 1:15,000 scale terrain map of the development area was prepared by EBA Engineering Consultants Ltd. (2002). From a groundwater perspective, surficial deposits are relatively thin over much of the development area. Bedrock is frequently found within five metres of surface in the western half of the development area. Thickest overburden deposits occur within the east portion of the study area along the Alaska Highway. Overburden thickness at the location of the Wolf Creek North subdivision test well is 37 m (Gartner Lee Limited 2000). Overburden is generally 16 m to 30 m thick in the MacRae industrial subdivision (Gartner Lee Limited 2002b).

## 2.1 Groundwater Flow

Existing groundwater information for the study area is limited. Six monitoring wells located along the Mt. Sima access road were installed in 1991 (Piteau Engineering Ltd. 1991a,b). Multiple private water wells are present to the south in the Wolf Creek Subdivision area. Information concerning these wells has been complied as part of the *Wolf Creek and Pineridge Water Well Database* (Gartner Lee Limited 2001a) and *Wolf Creek/Pineridge Subdivision Groundwater Usage Study* (Gartner Lee Limited 2001b). The locations of these wells, water table elevations and total depths are shown on Figure 3. Subsurface information is not available for much of the study area.

Static water elevations that are shown on Figure 3 are inferred from reported water levels in drilling records and from water elevations of nearby surface water bodies. In deriving the information that is shown on Figure 3, we have assumed that surface water bodies in the study area are hydraulically connected to a single aquifer and that perched conditions, if present, are developed at a scale that is smaller than that represented by the figure.




LEGEND:

- Proposed Development Area Footprint
- Interpreted Static Water Levels* (m ASL)

Known Well Locations (well completion)

- Unknown
- Bedrock
- Overburden

WL=688 Depth=61 — Static Water Level (m ASL), Total Well Depth (m)

* NOTE: Water table elevations interpolated from reported static water levels in drilling records (as shown) and surface water features.

Source of Basemap: City of Whitehorse 1:20,000 topographic base. 1996. Triathlon Mapping Corp.

Well Locations: Gartner Lee Limited, 2002b

Reviewed By: FKP

Drawn By: FKP

Date Issued: Nov. 2002

Project Number: 22-586

File Name: 22586-F3-R1.WOR

Revision: 1

**Well Locations and Interpreted Water Table Elevations**

**Preliminary Groundwater Assessment**
**Whitehorse Copper Development Area**
**Community Development Branch, YTG**

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Figure No. 3

The direction of groundwater flow is perpendicular to the equipotentials (static water level contours) that are shown in the figure. In general, groundwater in the study area flows toward the east (toward the Yukon River). Groundwater recharge will likely occur mainly in the upland areas, with groundwater discharge occurring near creeks, wetlands (fens) and, ultimately, the Yukon River.

Reference to Figure 3 indicates that very few private wells in Wolf Creek are hydraulically downgradient of the proposed areas of development. The most likely location for potential interactions between private wells within the proposed developments and Wolf Creek wells is near the south end of the proposed development within the Lots 103 to 133 area. These lots are inferred to be hydraulically upgradient from the private wells in the Harbottle and Boss Road areas. The balance of the Wolf Creek subdivision lies south of the proposed developments at locations that are inferred to be hydraulically transgradient to the local direction of groundwater flow and it is considered unlikely that there would be significant interaction between these areas.

## 2.2 Groundwater Development

For typical single residential domestic wells, yields of at least 13.7 L/min (3 Imperial gallons per minute, igpm) are desirable. Well yields as low as 5 L/min (1 igpm) can be viable. However, homes with such low-yield wells typically require larger pressure tanks and/or well-bore storage provisions to meet peak water demands. Homes equipped with low-yields wells are present in the Wolf Creek subdivision and more frequently in the Cowley Creek subdivision. Owners of such wells need to manage their wells carefully to prevent drawing water levels within the well down too low, temporarily depleting their well and damaging the well pump.

Successful, sustainable development of groundwater resources is contingent on three factors:

1. adequate rate of recharge (e.g. precipitation) that re-supplies water depleted from the groundwater system;
2. proper well construction and well management that considers environmental conditions; and
3. presence of suitable aquifer conditions.

Recharge requirements of the proposed subdivision area are discussed in Section 3 of this report. Well construction and geological materials are discussed in the following Sections.

### 2.2.1 Well Construction

Typically, residential wells near the proposed development areas are completed either in overburden (unconsolidated sediments) or bedrock aquifers. Wells completed in overburden are completed using well screens that holds back the aquifer material, but allow groundwater to flow into the well. Bedrock wells are typically completed as open boreholes that allow groundwater in fractures to enter the well bore. Some drillers in the Yukon complete overburden wells without screens. Completing overburden wells without screens can reduce well yields, increase turbidity (e.g. sand content) and increase maintenance and pumping electricity costs.

Most groundwater supply problems experienced in the *Wolf Creek/Pineridge Water Well Database Pilot Project* (Gartner Lee Limited 2001a) were related to well-construction issues. Therefore, good well construction techniques are critical to successful groundwater development.

Examples of water supply problems related to well construction seen in the Wolf Creek and Pineridge area include:

- overburden wells not completed with a well screen causing reduced well yields (e.g. well goes dry), increased turbidity, and premature pump failure.
- shallow well completion (e.g. <15 m depth) causing wells to go seasonally dry due to seasonal and environmental fluctuations
- low yield wells completed without adequate well bore storage causing well to go temporarily dry when over-pumped.

Generally, it is recommended that all water wells are constructed in accordance with best practices and/or water well construction standards such as the American Water Works Association Standard for Water Well Construction (A100-97).

### 2.2.2 Geological Setting

Groundwater resource potential is ultimately controlled by aquifer media—that is the bedrock and overburden geology that potentially hosts aquifers. Information on bedrock geology and surficial geology of the study area is limited, but what is known is summarized in the *Preliminary Groundwater Inventory of the City of Whitehorse* (Gartner Lee Limited 2002). The information contained in the report is overview in nature and presented at a 1:50,000 (regional) scale. No further detail can be provided until site specific hydrogeological field investigations are completed.

**Overburden Aquifer Potential**

Overburden materials within much of the study area are anticipated to be relatively thin (less than approximately 20 m in thickness). Furthermore, much of the study area is inferred to be underlain by till, which is typically not suitable for development of wells. A surficial geology map of the study area has been prepared (EBA Engineering Consultants Ltd. 2002), however little is knows regarding the thickness of the overburden deposits within the study area.

There may be some potential for development of overburden aquifers in the southeastern portion of the development where overburden is inferred to be, on average, somewhat thicker and, where investigated, typically consists of sand and gravel. However, development of potential overburden aquifers in this area will be via shallow wells that are likely to be susceptible both to seasonal fluctuations in the water table and contamination from septic fields and infiltration of surface water.

Because most private wells in the MacRae and Wolf Creek areas are completed in bedrock, it is considered likely that new wells in the proposed developments will be completed within bedrock aquifers. Locations of known overburden and bedrock wells are shown on Figure 3.

**Bedrock Aquifer Potential**

The footprint of the development is underlain by two primary bedrock units as shown on Figure 4:

1. Miles Canyon Basalt (volcanic);
2. Whitehorse Batholith (granodiorite).

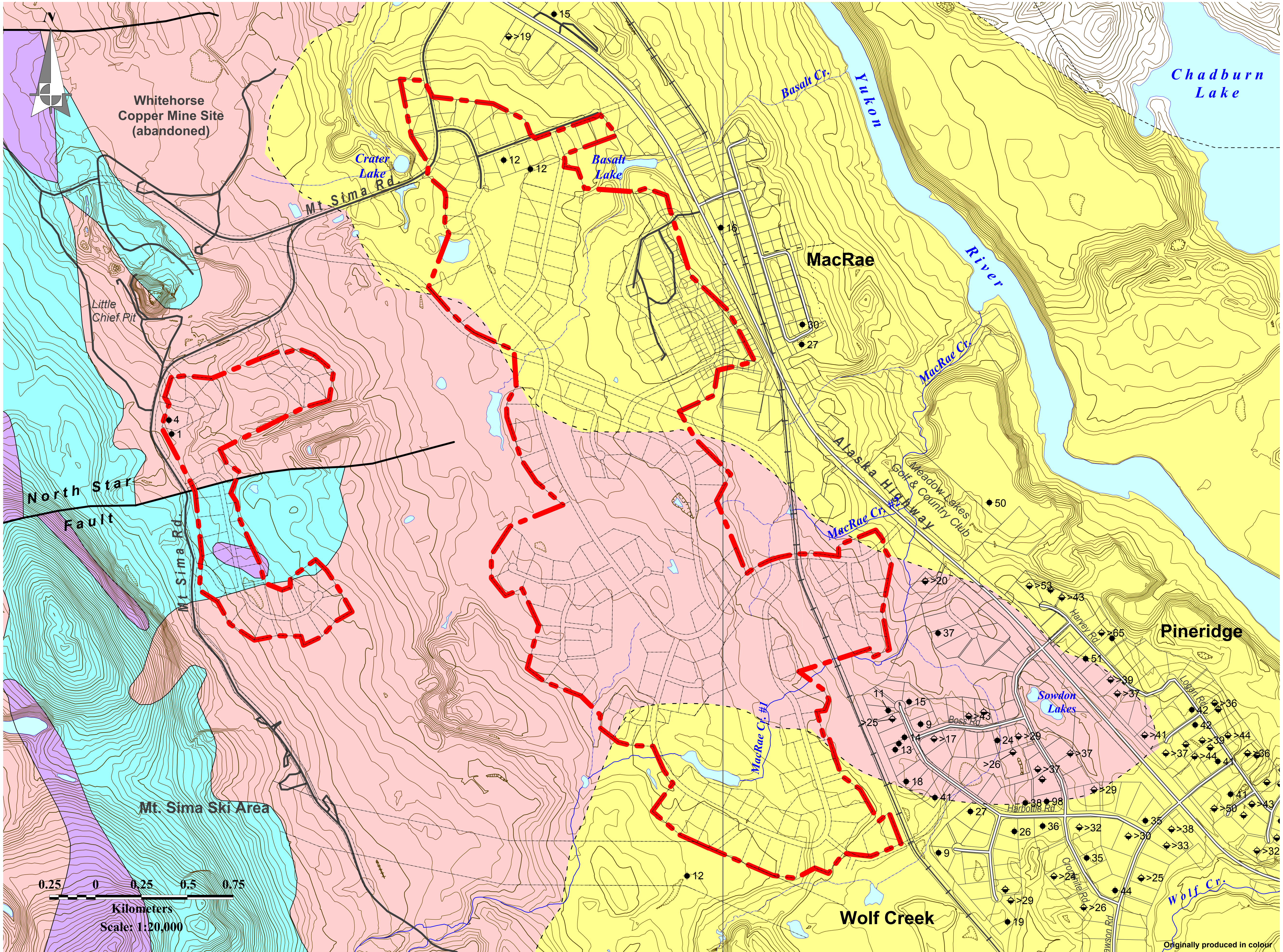
Available results of bedrock mapping in the study area are only available at a 1:50,000 scale. The exact locations of geological contacts and the thickness of geological units is not well defined.

Bedrock aquifers within the Miles Canyon Basalt have been successfully developed in many parts of the Wolf Creek, Pineridge and Mary Lake subdivision areas. These aquifers typically yield adequate water (quantity and quality) for residential purposes. This geologic unit occurs underlying the northeast portion of the proposed developments and within the southwest area south of MacRae Creek #1. The thickness of this the Miles Canyon Basalt is unknown and likely varies across the study area. Beneath some areas, the thickness of basalt may be insufficient to be developed for a water supply. Typical hydrogeological properties of this unit are described in "*Distribution of Miles Canyon basalt in the Whitehorse area and implications for groundwater resources"* (Pearson et al. 2000).

Granitic rocks of the Whitehorse Batholith are believed to underlie much of the study area. They are exposed at or subcrop beneath much of western half of the study area. These rocks underlie the Miles Canyon Basalts. This unit underlies many country residential subdivisions in Whitehorse, including Cowley Creek subdivision, portions of the Mary Lake subdivision and the western portion of the Wolf Creek subdivision where it has been developed as a residential groundwater resource. Most of the private wells in the Harbottle and Boss Road areas are completed in the granitic rocks of the Whitehorse Batholith.

Development of water supplies using aquifers of the Whitehorse Batholith can be difficult and expensive since the granodiorite is typically massive and crystalline with groundwater flow restricted to fractures and fault zones. Unfortunately, the location, extent and size of these fracture zones is impossible to predict. Many exploratory wells put down in this rock unit have been unsuccessful in producing adequate groundwater yields. Examples of unsuccessful wells include at least one well on Harbottle Road and a 200 m deep well at the Boyle Barracks Cadet camp. There are anecdotal accounts of wells that are completed in granodiorite and that have produced adequate yields in the Cowley Creek subdivision area, but groundwater in these wells are reported to be heavily mineralized and not suitable for residential use. Other wells may be successfully completed in the granodiorite, however yields are frequently reported to be low, (e.g less than 5 L/min).

In summary, historic development of successful domestic wells in the granodiorite has been "hit-or-miss" and depends on the chance of intercepting a water bearing fracture in the bedrock.




LEGEND:

Proposed Development Area Footprint

BEDROCK GEOLOGY*

- Miles Canyon Basalt
- Whitehorse Batholith (granodiorite)
- Hancock Formation (limestone)
- Mandanna Formation (sandstone, mudstone, shale)

WATER WELLS

- 34 Bedrock well (depth to bedrock in metres)
- >21 Deep overburden well (depth to bedrock in metres)

* NOTE: Location of geologic contacts shown on this map are approximate. No reliance should be made on these data until more detailed bedrock mapping is conducted.

Source of Basemap:
City of Whitehorse 1:20,000 topographic base. 1996. Triathlon Mapping Corp.
Bedrock Geology:
S.P. Gordey and A.J. Makepeace 1999, Yukon digital geology. Geological Survey of Canada Open File D3826

Reviewed By: FKP
Drawn By: FKP
Date Issued: Nov. 2002
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File Name: 22586-F4.WOR
Revision: 0

## Bedrock Geology and Depth to Bedrock

**Preliminary Groundwater Assessment**
**Whitehorse Copper Development Area**
**Community Development Branch, YTG**

Gartner Lee Limited

Figure No. 4

# 3. Water Supply Assessment

## 3.1 Recharge Assessment

The ability of soil to absorb and transmit infiltrating precipitation to the groundwater system(s) is an important consideration in assessing the potential environmental impact of a proposed development. For the purposes of this discussion, the portion of precipitation that infiltrates to the water table is considered to constitute groundwater recharge. Areas of high groundwater recharge potential are important, with respect to replenishing aquifers and susceptibility to contamination from chemical spills or surface sources of contamination such as road salt, fertilizers or sewage effluent from subsurface sewage disposal systems.

The purpose of assessing groundwater recharge conditions is twofold:

1. to determine if adequate recharge is likely to be available to replace groundwater consumption that is likely to be associated with the proposed development; and
2. to determine if adequate dilution conditions are likely to be present to help mitigate potential septic effluent infiltration impacts.

The method that is used in this study for estimating groundwater recharge involves using a climatic water budget and applying it to the area of the proposed development. A water budget was prepared by Environment Canada and was originally reported as part of the *Wolf Creek/Pineridge Subdivisions Water Usage Study* (Gartner Lee Limited 2001b). A detailed description of the methodology used to estimate the water budget is presented in this report. The water budget estimates a total annual water surplus for groundwater recharge to be 25 mm / year.

The rate of groundwater recharge depends on the amount of surplus water available from the water budget as well as site-specific conditions including topography (slope), soil type and forest cover. The method for estimating groundwater recharge that is used in this study based on a method described in the *Hydrogeological Technical Information Requirements for Land Development Applications* (Ontario Ministry of the Environment 1995). This methodology is widely used in Ontario for assessment of this style of development (e.g. rural residential).

The magnitude of the infiltration factor that is used in the calculations is obtained by summing the appropriate values for topography, soil and cover type. The effects of the infiltration factor is applied to the estimated available surplus water to estimate groundwater recharge. The infiltration factors that are used in this study are based on the results of a hydrologic analysis that were designed for assessing peak runoff for stormwater management purposes. This provides a worst case scenario with respect to runoff and is conservative in estimating the amount of groundwater recharge.

### 3.1.1 Topography Factor

In the MOE manual, three discrete categories of topography are described:

**Table 1. Topographic Infiltration Factors**

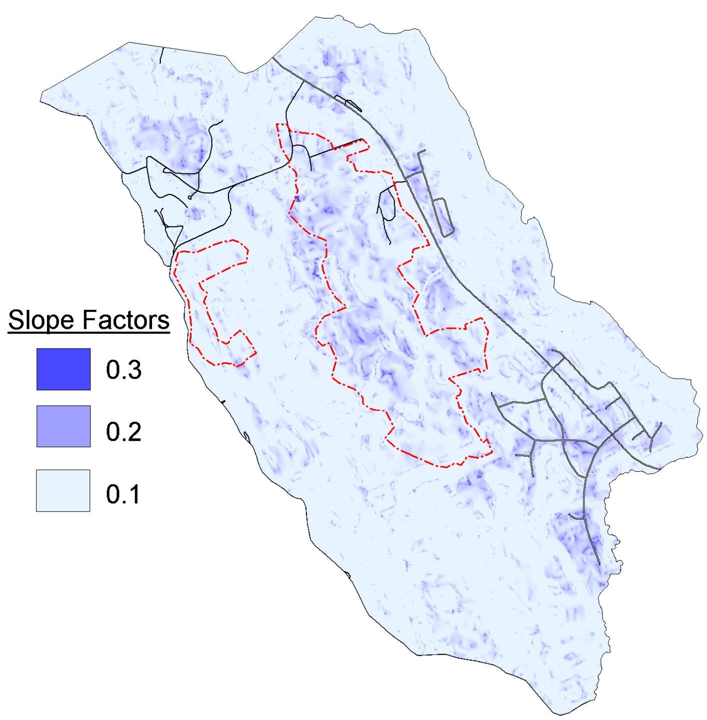
| Description of Area | Value of Infiltration Factor |
|---|---|
| Flat land, average slope not exceeding 0.6 m per km | 0.3 |
| Rolling land, average slope of 2.8 to 3.8 m per km | 0.2 |
| Hilly land, average slope of 20m to 47 m per km | 0.1 |

In order to estimate this factor, a digital elevation model of the study area was constructed based on the digital terrain points of the City of Whitehorse (Triathlon Mapping Corp. 1996). These elevation points were assembled into a TIN (triangulated irregular network) then transformed to a grid with a 10m cell size. Application of the generalized infiltration factors recommended by MOE was refined by developing a relationship between infiltration factor and degrees of slope. For the two categories where slope ranges were given, the appropriate slope (in degrees) was calculated for the maximum-point of the range. The relationship between slope and infiltration factors can be described by a power fit regression as shown in the following equation:

$$\textbf{Slope Infiltration Factor} = 0.1306*(\textbf{Slope angle})^{-0.2527}$$

This relationship was used to derive an infiltration factor based on slope. For slopes less than 0.03°, the infiltration factor was assigned to 0.3. For slopes greater than 2.7°, the infiltration factor was assigned to 0.1. The topography-related factors are shown in Figure 5.

**Figure 5. Infiltration Factor based on Topography**



### 3.1.2 Soil Infiltration Factor

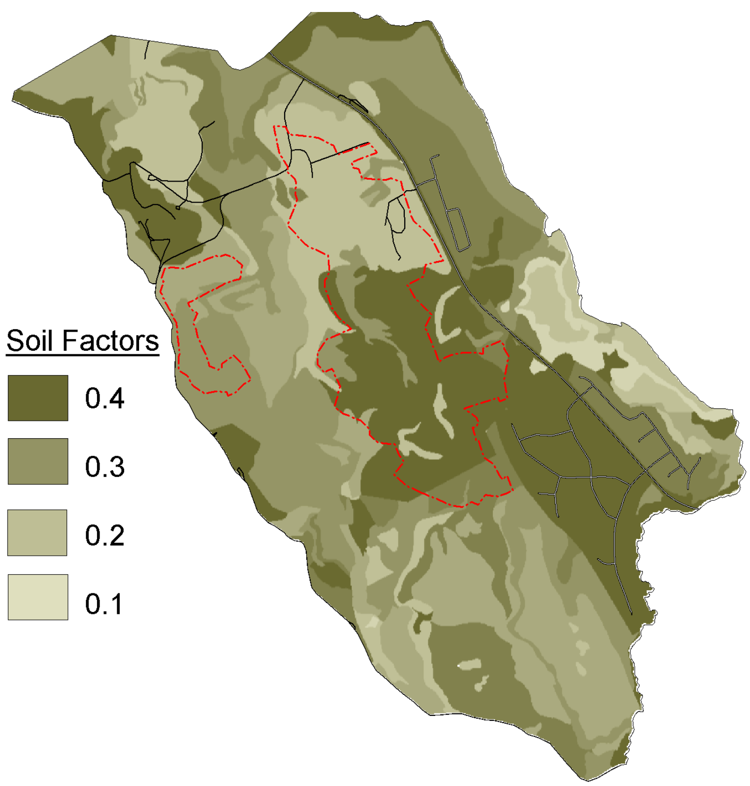
The component of the total infiltration factor due to soil effects was estimated using the results of terrain mapping by EBA Engineering Consultants Ltd. (2002) supplemented by the city wide surficial geology map by Mougeot GeoAnalysis and Agriculture and Agri-Foods Canada (1996). Guidance for values of soil infiltration factors that is provided by MOE is as follows:

**Table 2. Soil Infiltration Factors**

| Description | Soil Infiltration Factor |
|---|---|
| Tight Impervious Clay (e.g. glaciolacustarine) | 0.1 |
| Medium combinations of clay and loam (e.g. till) | 0.2 |
| Open sandy loams (e.g. $F^G$ sand & gravel) | 0.4 |

Interpolation between the factors listed in Table 2 was used to estimate the value of a soil infiltration factor when soil mixtures are present within a single map unit. The resulting soil infiltration factor map is shown in Figure 6:

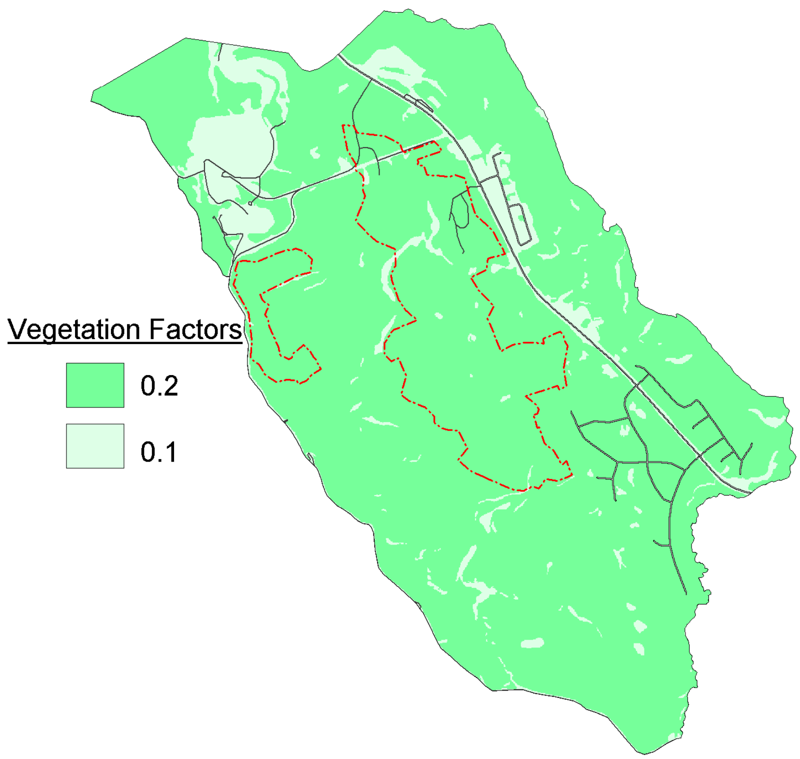
**Figure 6. Soil Infiltration Factors**



## 3.2 Cover Factor

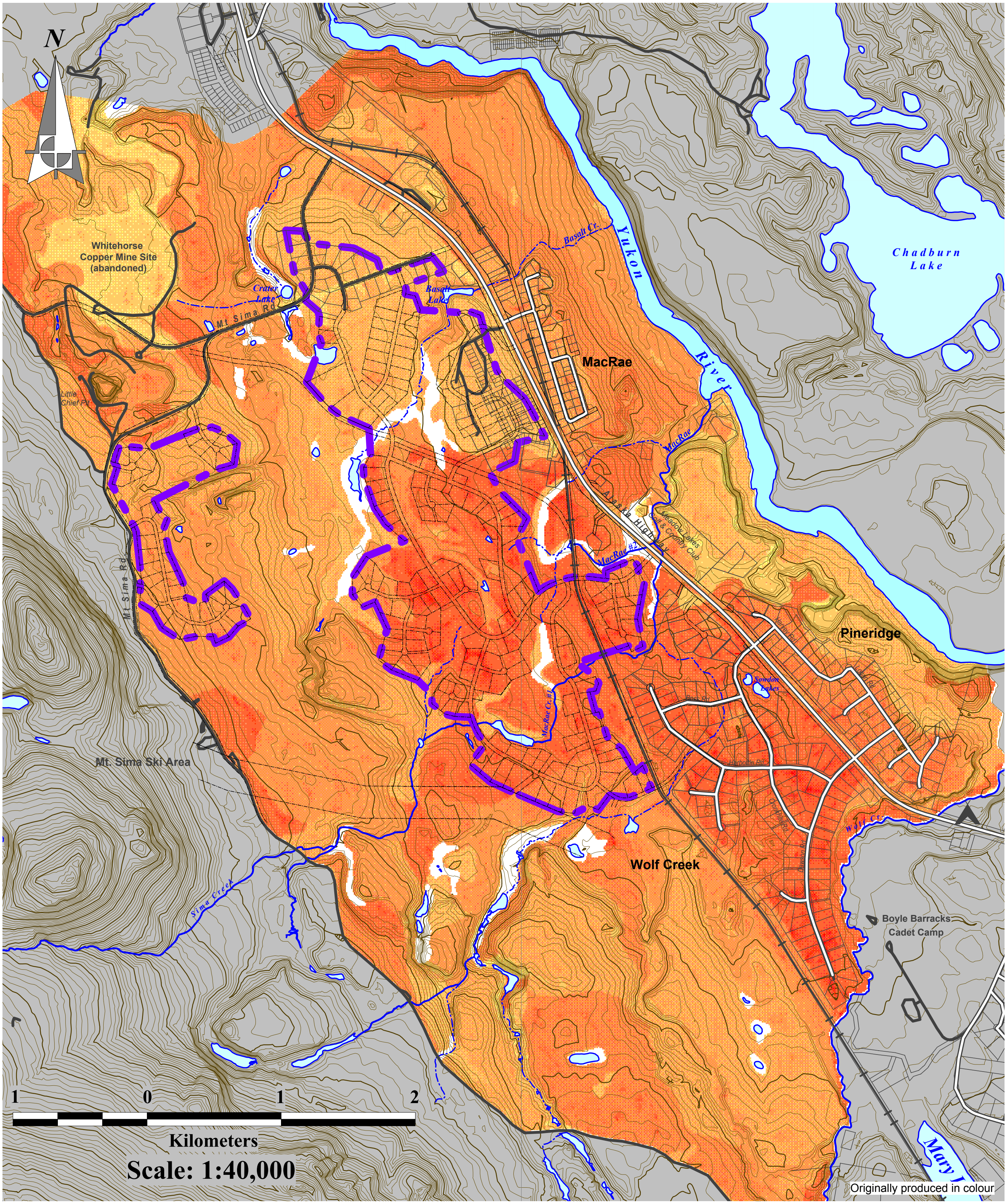
The third factor used in the MOE methodology accounts for land-cover effects. In this case, there are two factors applied, based on whether the area is forested or open. To estimate this factor, a grid of the study area was constructed using the distribution of forest that is shown on City of Whitehorse 1:20,000 scale topographic mapping (Figure 7). Vegetated land and non-vegetated land are assigned cover infiltration factor values of 0.2 and 0.1, respectively.

**Figure 7. Vegetation Infiltration Factors**




### 3.2.1 Total Infiltration Factors

The total infiltration estimates for the study area were calculated by summing the individual factors of topography , soil and vegetation cover within the GIS. For areas of groundwater discharge that are identified in the City-wide groundwater inventory (Gartner Lee Limited 2002b), infiltration effects were assigned a value of zero. Discharge areas within the study areas are shown as white on Figure 8.




Infiltration (mm/year)
- 7.5
- 10.0
- 12.5
- 15.0
- 17.5
- 20.0
- 22.5

Proposed Development Area Footprint

Recharge Not Calculated

Source of Basemap:
City of Whitehorse 1:20,000 topographic base. 1996. Triathlon Mapping Corp.

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# Infiltration

**Preliminary Groundwater Assessment**
**Whitehorse Copper Development Area**
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Figure No. 8

The results of recharge modelling using the MOE method, modified as discussed above, are shown on Figure 8. Based on the information shown on this figure, the estimated total annual infiltration over the proposed subdivision footprint of 590 ha (outlined in purple on Figure 8) is approximately 91,000 $m^3$/year. It is important to note that this does not account for any recharge occurring upslope (e.g. west) of the proposed development area, which is an additional and significant source of groundwater recharge. Table 3 has been prepared to compare the estimated recharge over the proposed development with that for the Wolf Creek/Pineridge subdivision area:

**Table 3. Modelled Recharge Values for Proposed and Existing Developments**

| Recharge Area | Area (ha) | Estimated Recharge ($m^3$/year) |
|---|---|---|
| Proposed Development | 590 | 91,000 |
| Wolf Creek/Pineridge Subdivisions | 320 | 55,600 |

For the Wolf Creek/Pineridge area, the estimated recharge volumes are similar to those predicted in the *Wolf Creek/Pineridge Water Usage Study* (Gartner Lee Limited 2001b). It is important to note, however, that the Wolf Creek/Pineridge Water Usage Study estimates included the estimated effects of recharge from hydraulically up-gradient and adjacent lands. For the purposes of this assessment, the recharge areas have been assumed to be considerably smaller to produce a conservative assessment.

## 3.3 Groundwater Consumption Assessment

To estimate the rate of groundwater removal from the proposed development, it is assumed that each of the proposed 156 residential and 56 industrial lots will rely on private water wells and on-site septic disposal. For such developments, it is typically assumed that all water pumped from the ground will be returned to the aquifer via septic field discharge (Ministry of Environment 1995). However, in order to make a conservative assessment, for this project, a more detailed assessment of the water usage has been conducted as follows.

Overall, the water usage balance may be defined as follows:

**Groundwater Consumption = Demand – Septic Recharge to Aquifer(s)**

Where:

**Consumption** is the water used, but not returned to the aquifer(s);
**Demand** is total volume of water pumped from the well and used on the property

### 3.3.1 Groundwater Demand

Residential Water Demand is estimated as follows:

**Residential Demand** **= Personal Usage + Lawn and Garden Watering**
= (301 $m^3$/year) + (68 $m^3$/year)
= 370 $m^3$/year/household

Where:

**Personal Usage** = (0.275 $m^3$/person/day) x (3 people/household) x (365 days/year)
= 301 $m^3$/year/household.

**Lawn and Garden Watering** = (225 $m^2$) x (0.025 m/week) x (12 weeks)
= 68 $m^3$/year/household

Estimated average personal water demand is based on information appearing in *Ontario Rural Residential Design Manual* (1995). The estimate is slightly lower than that assumed for the 2001 Wolf Creek/Pineridge Water Usage Study. However the 2001 Wolf Creek/Pineridge Water Usage Study did not account for lawn and garden watering separately. The average number of people per residence has been assumed to be three, which is larger than the Yukon average of 2.7 people per household (Yukon Bureau of Statistics 1997), but similar to that seen in the Pineridge Subdivision area (e.g. 3.05 people/household) (Gartner Lee Limited 2001b). In summary, the water usage values used in this assessment are consistent with previous estimates of Yukon water consumption rates.

In estimating water consumption for lawn and garden watering, it is assumed that each household irrigates a lawn and garden that has an average area of 225 $m^2$ (e.g. 15 x 15 m). Average irrigation rates are assumed to be 0.025 m/week (1-inch week) over the period of June to August.

Service Industrial water demand is estimated as follows:

**Service Industrial Demand** = (0.275 $m^3$/person/day) x (5 employees) x (87 occupied days/year)
= 120 $m^3$/year

Where:

**Occupied Days** = (8 hours / 24 hour day) x (5 days/week) x (52 weeks)
= 87 days

The proposed development area also provides for a school. It is anticipated that the school would be similar in size to other rural elementary schools in Whitehorse. The Hidden Valley School is likely to be representative of the school in the study area. The Hidden Valley School uses trucked water delivery and uses approximately 775 $m^3$ of water per year (Hrebien, pers. comm. 2002). It is reported that less than 10 percent of the delivered water is used for watering of the playing field.

Estimated total water demand for the proposed development, assuming each lot is serviced by an on-site well is:

**Table 4. Summary of Estimated Groundwater Demand**

| Type | Number of Units | Demand / Unit ($m^3$/year) | Total Demand ($m^3$/year) |
|---|---|---|---|
| Residential | 156 | 370 | 57,720 |
| Service Industrial | 64 | 120 | 7,680 |
| School | 1 | 775 | 775 |
| Total Demand | | | 66,200 |

Given the predicted groundwater conditions, it is likely that many of the residences will opt for trucked water delivery over development of an on-site well. Therefore, the assumption that all properties will develop an on-site well is conservative.

### 3.3.2 Septic Recharge Rate

It is difficult to estimate what portion the water demand returns to the aquifer via infiltration of septic effluent. It is assumed that water that is used for lawn and garden watering does not recharge the aquifer and that this represents the major water loss in the household. Traditionally it has been assumed that 100 percent of septic effluent returns to the aquifer. However, it has been observed locally that vegetation frequently grows more vigorously over septic tile fields. This suggests that some of the septic discharge is being intercepted by the plant roots and thereby being lost to evapotranspiration. To our knowledge there has been no research conducted to date to determine what percentage of septic discharge actually returns to the groundwater flow system. Therefore, it is assumed that 10 of the personal water usage is lost to a combination of evaporation within the household and evapotranspiration over the septic tile bed. For example:

**Evapotranspiration Loss = Personal Water Usage x 10%**

= 301 $m^3$/year/household x 0.1

=30 $m^3$/year/household

### 3.3.3 Groundwater Consumption

It is assumed that 100 percent of residential personal water usage and 100 percent of Service Industrial groundwater usage will be discharged to the septic field. Therefore, losses to the groundwater system, or groundwater consumption, will be limited to irrigation (lawn and garden watering) losses and septic field evapotranspiration losses. Table 5 provides a summary of the estimated groundwater consumption for the proposed development:

**Table 5. Predicted Groundwater Consumption**

| Type | Lawn & Garden Watering ($m^3$/year) | Evapotranspiration Loss ($m^3$/year) | Number of Units | Total Consumption ($m^3$/year) |
|---|---|---|---|---|
| Residential | 68 | 30 | 156 | 15,288 |
| School | 77 | 77 | 1 | 154 |
| Service Industrial | - | 12 | 64 | 768 |
| Total Consumption | | | | 16,210 |

Therefore, using the above assumptions, the maximum estimated water consumption (groundwater utilized and not returned to the aquifer) for the proposed development would be approximately 16,210 $m^3$/year. The estimated groundwater recharge over the development footprint alone is approximately modelled to be 91,000 $m^3$/year. Therefore the estimated rate of recharge over the development footprint can support the estimated rate of groundwater consumption within the proposed development. This conclusion does not account for the effects of additional recharge that is likely to occur hydraulically upgradient of the study area, which would provide additional groundwater recharge to the development area.

# 4. Septic Disposal Impact Assessment

### 4.1.1 Environmental Impact Assessment Methodology

The impact of septic disposal systems on groundwater quality below the proposed development area and adjacent boundaries (e.g. downgradient) is important to consider. Generally, the most critical potential groundwater contaminant from septic effluent and that can be meaningfully evaluated is nitrate (expressed as nitrogen). Potential effects of pathogens in septic effluent (such as bacteria and viruses) are also important to consider but are not able to be meaningfully evaluated, at the screening level. The Canadian Drinking Water Quality Guideline (CDWQG) for nitrate-nitrogen is 10 mg/L. It, therefore, should be demonstrate that groundwater quality beneath the proposed development area following development is likely to continue to meet this guideline.

For the purposes of this project the Ontario Ministry of Environment (MOE) document *Technical Guideline for Individual On-Site Sewage Systems: Water Quality Impact Risk Assessment* (1995) methodology has been followed. This methodology consists of three steps:

1. Lot Size Considerations - In Ontario, detailed assessments of septic disposal impacts are not required for developments with average lot sizes exceeding 1 ha. This is because it is typically assumed that effluent-attenuation processes are likely to take place within a 1 ha lot will be sufficient to reduce the concentration of nitrate-nitrogen in septic effluent to an acceptable concentration. This assumes that a properly constructed and maintained septic systems that have been installed in accordance with applicable regulations. However, as the water surplus in Whitehorse is relatively small and because of concerns that have been expressed by residents of the area near the proposed subdivision, a more detailed assessment has been completed as follows.

2. System Isolation Considerations – Overburden thicknesses across the study area are anticipated to be relatively thin (i.e. less than approximately 20 m). The overburden in many areas is likely to be relatively permeable, and will not significantly prevent the septic effluent from returning to the water supply aquifers. It follows that private wells that are completed within the proposed subdivision will be developed in either bedrock or shallow overburden aquifers that will have limited protection from surface water and septic discharges. For example, it is unlikely that a thick sequence of silt and clay exists in the study area that could isolate the water supply aquifer(s) from the septic discharges. Therefore the detailed mass balance methodology as discussed below has been used.

3. Contaminant Attenuation – System isolation is anticipated to be insufficient in the study area—in other words it is unlikely that there will be significant vertical separation between the water supply aquifers and the septic discharges. A mass balance approach has been used to estimate average nitrate-nitrogen levels that will be produced from the proposed development and its potential effects both on and off the site in the groundwater system. The MOE (1995) predictive assessment

methodology for residential development has been used to estimate mass balances. We have assumed for this screening level assessment that dilution is the only quantifiable mechanism for attenuation of nitrate. The dilution model assumes that nitrate-nitrogen concentrations in infiltrating septic effluent are diluted with infiltrating precipitation only. Groundwater mixing effects have not be considered in the assessment. This is a conservative assessment approach. However it is unlikely that there will be significant development hydraulically upgradient from the proposed development and groundwater flowing through the study area will provide an extra degree of dilution that is not accounted for in this mass balance.

### 4.1.2 Proposed Development Impact

The mass balance approach to contaminant attenuation for the proposed development is determined as follows:

$$\mathbf{Q_T C_T = Q_1 C_1 + Q_2 C_2}$$

where:

$\mathbf{C_T}$ = total nitrate concentration in groundwater from septic discharges (maximum of 10 mg/L allowable)

$\mathbf{C_1}$ = background nitrate concentration in rainwater (assume 0 mg/L)

$\mathbf{C_2}$ = nitrate concentration in septic effluent assuming all nitrogen converts to nitrate = 40 mg/L (MOE 1995)

$\mathbf{Q_1}$ = groundwater recharge for dilution over proposed development (see Section 3.1) = 91,000 $m^3$/year

$\mathbf{Q_2}$ = annual septic effluent volume from household, service industrial and school water use
= (301 $m^3$/year x 156 homes)+(120 $m^3$/year x 64 industrial lots)+(775 $m^3$/year x 1 school)
= 55,411 $m^3$/year

$\mathbf{Q_T}$ = total effluent dilution volume = groundwater recharge ($Q_1$)
**=** 91,000 $m^3$/year

Solving for resulting nitrate-nitrogen concentration:

$$\mathbf{C_T = (Q_1 C_1 + Q_2 C_2) / Q_T}$$

$$\mathbf{C_T} = (91{,}000\ m^3/\text{year x } 0\ mg/L) + (55{,}411\ m^3/\text{year x } 40\ mg/L) / (91{,}000\ m^3/\ \text{year})$$

$$= 24\ mg/L$$

The above mass-balance calculation contains a number of conservative assumptions in order to generate a "worst-case" estimate for planning purposes. Actual nitrate levels in groundwater as a result of development activities are expected to be significantly lower for the following reasons:

- Denitrification processes (not accounted for in the equation above) in the subsurface will remove some nitrate mass from groundwater;
- The recharge model tends to under-estimate the amount of recharge occuring, and therefore under-estimates the dilution capacity of the system;
- Additional groundwater recharge sources have not been incorporated in the model, such as recharge upgradient of the site, effluent streams, and closed depressions that do not allow runoff.
- The calculation assumes all nitrogen in septic effluent is converted to nitrate;
- The nitrate concentration of septic effluent used in the calculation, as stipulated in the MoE methodology (40 mg/L), is double the concentration expected in typical waste water streams (15 to 20 mg/L (Metcalf & Eddy 1991)).

The above assessment considers characteristics of the groundwater flow system at the proposed development areas at the scale of the proposed subdivision. The assessment does not address the potential for existing or future private wells to be impacted by the individual septic fields that may exists within the existing development or within the proposed development. Assessment of such potential impacts would require a level of analysis that is on the scale of a septic field and is beyond the scope of the present investigation. Septic effluent impacts to private wells will occur when groundwater wells are hydraulically down gradient from a septic field and subsurface conditions between the septic field and the wells are not capable of sufficiently attenuating septic effluent prior to its being drawn into the wells. This effect can happen in any location within any rural residential subdivision. The effluent-attenuating capacity of glacial deposits such as those that are present in the study area are capable of varying at scales of on the order of a septic field. Accordingly, assessing subsurface attenuation capacity and the likelihood that a given septic field is likely to impact specific wells is considered to be a site-specific issue that is best evaluated on a lot-by-lot basis prior to the installation of wells and septic fields. Maintaining standard separation distances between wells and septic fields (30 metres) and installing septic fields downgradient of wells will minimize the risk of nitrate contamination at the local (lot) scale.

### 4.1.3 Existing Conditions at Wolf Creek and Pineridge

A groundwater quality study for the Wolf Creek and Pineridge subdivision area has recently been completed (Gartner Lee Limited 2002a). First development of the Wolf Creek subdivision occurred in the late 1970s and as such it is one of the oldest country residential subdivisions in Whitehorse. This development included a total of 195 residences and has an average lot density of 0.7 homes/ha. This is a significantly higher density than the proposed development. The existence of the subdivision provides an opportunity to assess groundwater impacts from actual rural residential development.

As part of the Wolf Creek and Pineridge groundwater quality study, groundwater from 22 of the subdivisions' private wells were analyzed for chemical variables including nitrate-nitrogen. This study identified an average nitrate-nitrogen concentration in groundwater samples of 1.5 mg/L, with concentrations ranging between less than 0.1 mg/L to 10.8 mg/L. Overall, nitrate-nitrogen concentrations in groundwater were found to be low, with two anomalous elevated concentrations near the southwest corner of the subdivision. These two anomalies are suspected to be related to off-site issue and considered not likely to be related to on-septic effluent issues associated with subdivision itself.

Using the same methodology to estimate the average concentration of groundwater nitrate leaving the Wolf Creek/Pineridge subdivisions as was used in Section 4.1.2, the nitrate-nitrogen mass balance model for the Wolf Creek/Pineridge area is as follows:

| | |
|---|---|
| **$C_1$** = | background nitrate concentration in rainwater effective recharge (assume 0 mg/L) |
| **$C_2$** = | nitrate concentration in septic effluent assuming all nitrogen converts to nitrate = 40 mg/L (MOE 1995) |
| **$Q_1$** = | groundwater recharge for dilution over subdivision footprint (see Section 3.1) = 55,600 $m^3$/year |
| **$Q_2$** = | annual septic effluent volume from household use (see *Wolf Creek/Pineridge Water Usage Study* (Gartner Lee Limited 2001b)) |
| = | 46,000 $m^3$/year |
| **$Q_T$** = | total effluent dilution volume = groundwater recharge ($Q_1$)) |
| **=** | 55,600 $m^3$/year |

$$\mathbf{C_T} = (76{,}000\ m^3/\text{year x } 0\ mg/L) + (46{,}000\ m^3/\text{year x } 40\ mg/L) / (76{,}000\ m^3/\ \text{year}) = 33\ mg/L$$

The estimated bulk concentration of groundwater nitrate-nitrogen that is predicted by the model is significantly higher (on the order of a factor of 10) than measured concentrations of nitrate-nitrogen concentrations in the groundwater within the subdivision. This is consistent with the conservative nature of the mass balance model and its underlying assumptions. Therefore, the water quality resulting from the proposed new development is likely to be significantly lower than that predicted in this assessment.

# Conclusions and Recommendations

The following conclusions and recommendations are based on the assessment described earlier in the report:

1. It is likely that most new wells in the proposed developments will be completed in bedrock. This is due to the anticipated widespread presence of relatively thin and/or low-permeability overburden deposits that, in most locations, are unlikely to contain aquifers

2. Over half of the proposed development area is likely to be underlain by granodiorite bedrock. Historically, development of private wells in this rock type has proven to be difficult, expensive or unsuccessful. Trucked water delivery may be a more viable alternative for homes in areas underlain by granodiorite bedrock.

3. Only a small portion of the proposed development is hydraulically upgradient from theexisting country residential subdivisions of Wolf Creek and Pineridge. Most of the wells and septic fields that will be installed in the proposed development are expected to have no effect on exisiting groundwater users in Wolf Creek and Pineridge because of the groundwater flow direction.

4. The estimated annual groundwater recharge rate over the proposed development footprint exceeds the estimated groundwater consumption rate, indicating that development of the proposed subdivision is unlikely to deplete groundwater resources in the area.

5. The modelled nitrate concentrations in the Whitehorse Copper area following development are lower than the modelled (current) concentrations in groundwater from the Wolf Creek subdivision. The model concentrations for the existing Wolf Creek Subdivision are in turn higher than the actual measured concentrations. Furthermore, recently measured concentrations of nitrates in groundwater samples from the Wolf Creek subdivision met Canadian Drinking Water Quality Guidelines with a few exceptions. These results indicate that nitrates introduced to groundwater from septic loading in the Whitehorse Copper development area are unlikely to pose health concerns to groundwater users in the area. However, it is recommended that routine monitoring of groundwater quality from the Whitehorse Copper area be conducted as the development proceeds.

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