



Yukon Groundwater and Ground Source Heat Potential Inventory

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Energy Solutions Centre Inc.

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Gartner Lee Limited

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Gartner Lee Limited

December 16, 2003

Mr. Ron Gee
Energy Solutions Centre
206A Lowe Street
Whitehorse, Yukon
Y1A 1W6

Dear Mr. Gee:

Re: 22680 - Yukon Groundwater and Ground Source Heat Potential Inventory

Gartner Lee Limited is pleased to present the attached report that summarizes the results of our investigations for the above-referenced project. This report is comprehensive in its scope and will prove to be a valuable resource for assessing groundwater and ground thermal issues in the Yukon. Thank you for the opportunity to undertake this project.

Yours very truly,
GARTNER LEE LIMITED

Alexander C. Bath, M.Sc., P.Geo.
Senior Hydrogeologist, Project Manager

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Executive Summary

Energy Solutions Centre Inc. (ESC) has a mandate to promote and develop alternative and sustainable energy resources in the Yukon. Ground-source heat energy is one such resource. Ground-source heat energy is exploited through ground-source heat pump (GSHP) technology. This technology is desirable because it is environmentally benign; it does not generate harmful emissions or exhaust. Although GSHP systems require electricity to operate, the technology's high efficiency (as high as 400 per cent) typically results in reduced emissions of carbon dioxide, sulfur dioxide and nitrous oxides, relative to those associated with conventional (fossil-fuel burning) heat energy systems.

Generally, ground-source heat energy can be developed using two types of systems:

1. GSHPs or groundwater heat pumps (GWHPs), also known as “Open Loop” systems; and
2. Ground-Coupled Heat Pumps (GCHPs), also known as “Closed Loop” systems.

GWHPs are, typically, more cost-effective and efficient than existing alternatives. However, use of GWHPs requires the presence of suitable groundwater resources. In some areas of the Yukon, development of GWHPs may be difficult due to the lack of suitable groundwater resources or other technical constraints. Use and selection of the best GSHP for a particular application is largely dependent on site-specific geological and hydrogeological conditions. Currently, there is little readily available information regarding groundwater resources, groundwater potential and ground temperatures across the Yukon.

Ground-source heat pumps are one of the most efficient means of heating homes, offices, schools and community buildings. The technology extracts and transfers heat energy from the earth or energy in a body of water using the same principles that allow refrigerators to extract heat from food and transfer it to the surrounding environment. The high efficiency of heat pumps enables them to supply significantly more heat than could be generated if the electricity needed to run the heat pump were used to produce heat using other means.

The overall project objective was to carry out a preliminary assessment of the Yukon's documented groundwater resources and their potential for exploitation using GSHP technology. This objective has been met by creating and populating a water well database for the principal Yukon communities (16 in total) using available information that is identified in publicly available water well records and some purchased drilling records. Using the compiled and structured information in the database, Gartner Lee Limited (Gartner Lee) assessed the GSHP potential for 16 Yukon communities. The communities that were investigated are:

Beaver Creek	Keno	Village of Teslin
Burwash Landing	City of Dawson	Pelly Crossing
Destruction Bay	Town of Faro	Town of Watson Lake
Village of Haines Junction	Ross River	Old Crow
City of Whitehorse	Carcross	
Village of Mayo	Village of Carmacks	

Water Well Database

Water well databases are useful for managing groundwater and ground-thermal resources. Unfortunately, the Yukon currently lacks an established water well database. To this end, Gartner Lee created a spatial-digital water well database for this project. An electronic copy of the database is saved on the CD-ROM that accompanies this report. The database is relational and contains the following types of data:

- well locations (in Universal Transverse Mercator (UTM) coordinates);
- well-location accuracy information;
- well construction details;
- well utilization and status information; and
- lithology.

The database currently contains records for 724 wells, 277 of which include geologic information (soil stratigraphy).

Ground Source Heat Potential

Based on information that is summarized in the report, Gartner Lee assessed the potential for GSHP development opportunities for the 16 investigated communities. A summary of GSHP development potential appears in the following tables.

Table I. Summary of GSHP for Rural Yukon Communities

Community	Groundwater Heat Pump (GWHP)		Ground Coupled Heat Pump (GCHP)	
	Potential	Comments	Potential	Comments
Beaver Creek	Moderate to High	• Successful historic development of groundwater for drinking. Details concerning groundwater temperatures are not well established. • Groundwater quality for GWHP appears to be relatively good, however some groundwater may be hard.	Moderate	• Subsurface soil is likely to be mainly saturated sand and gravel. • Potential impacts of permafrost on GCHP long-term efficiency are not known to Gartner Lee. • Depth to bedrock is uncertain and may be less than 30 m.
Burwash Landing	Moderate to High	• Historic development of groundwater for drinking suggests widespread presence of hard groundwater. • Winter shallow groundwater temperatures are suspected to be cold due to proximity of land surface and/or surface water. • Water quality for GWHP appears to be relatively good. • There is a potential for development of groundwater from deeper aquifers that may yield higher temperature water.	Moderate to Good	• Good potential exists for thermal transfer due to groundwater flow through saturated alluvial gravels. However, till may occur at depth.
Carcross	High	• High yield aquifers potentially exist at depth and several underutilized wells are present (e.g. school well, old firehall well and YTG maintenance yard wells). • Opportunities are likely to exist for GWHP using groundwater from the deeper aquifer and rejecting cooled water to the shallow aquifer.	Low to Moderate	• Soil, in general, becomes finer at depth, suggesting the potential for lower soil thermal conductivity with depth. However, drilling should be relatively easy.
Carmacks	High	• High yield aquifers exist near surface. • Groundwater temperatures appear to be relatively stable and somewhat warm. Most private wells may be suitable for use as private GWHP systems. • Poor water quality may require special consideration during design and operation of GWHP systems. • Groundwater re-injection should be relatively easy. • Warmer groundwater occur at depth within unconsolidated sediments.	Moderate to Good	• Abundant coarse grained saturated soil should provide relatively good thermal conductivity. • Good groundwater flow conditions under the community is anticipated.

Table I. Summary of GSHP for Rural Yukon Communities

Community	Groundwater Heat Pump (GWHP)		Ground Coupled Heat Pump (GCHP)	
	Potential	Comments	Potential	Comments
Dawson City	Low to Moderate	• Very low groundwater temperatures occur seasonally due to surface water influence. • Some potential for groundwater development exists in the Klondike Valley, but groundwater temperatures are not documented. • Groundwater quality may be an issue locally due to elevated concentrations of iron.	Low to Moderate	• Fine grained, ice-rich soil is common. • Impact of permafrost on GCHP performance is not known to Gartner Lee. • Areas of mined gravel (dredge tailings) may be well suited to GCHP due to potential for presence of saturated gravel. • Presence of shallow bedrock may limit GSHP borehole depths due to economics. • Potential exists for heat pump combination systems for i.e. space heating and ground-thaw protection (e.g. permafrost maintenance systems under buildings). • Potential exists for pond-loop GSHP application in dredge ponds.
Destruction Bay	Low to Moderate	• Low groundwater temperatures and poor water quality are common. • Potential exists for better quality and/or higher temperature groundwater in deeper aquifers (if they are present).	Moderate	• Soil is mainly glacial till. • Borehole depths required for GSHP systems are not likely to be limited by shallow bedrock.
Faro	Low to Moderate	• High-yield wells and an over-sized groundwater-production and -distribution system are present. • Low groundwater temperatures (due to surface water influence) and water quality issues are typical. • Minimal potential for groundwater development beneath the community.	Low	• Soil is primarily glacial till and unsaturated. • Bedrock is shallow, likely economically limiting GSHP borehole depths. • Discontinuous permafrost conditions are present. • Potential impacts of permafrost on GCHP long-term efficiency are not known to Gartner Lee.
Haines Junction	Moderate to High	• Warm high-yield flowing artesian groundwater at Well No. 5 (15° C) represents an exceptionally good opportunity. • Development of other aquifers will be difficult and wells will need to be deep.	Low to Moderate	• Soil is primarily fine grained. • No shallow bedrock to limit borehole depths.
Keno	Low	• Little documented information with respect to well yields, groundwater quality or temperature. • Groundwater development may be difficult, the community well is deep.	Low	• Soil is likely mainly coarse grained colluvium, till and unsaturated. • Presence of shallow bedrock is likely to be limiting to GSHP applications due to economics.

Table I. Summary of GSHP for Rural Yukon Communities

Community	Groundwater Heat Pump (GWHP)		Ground Coupled Heat Pump (GCHP)	
	Potential	Comments	Potential	Comments
Mayo	High	- Warm water (up to 15 degrees Celsius) is produced by the Village's warm water well and represents an exceptionally good opportunity. - Potential water quality issues will require careful management (in light of the failure of previous heat pump systems and water well).	Low to Moderate	- Soil is mainly fine grained - No shallow bedrock to limit borehole depths.
Old Crow	Low to Moderate	- Low groundwater temperatures are anticipated due to presence of permafrost. - Wells potentially have adequate yield.	Low	- Fine grained frozen soil is widespread. - Impact of permafrost on GCHP performance is not known to Gartner Lee.
Pelly Crossing	High	- Shallow high yield aquifers are present. - Groundwater temperatures appear to be relatively stable and relatively warm. - Potentially poor quality groundwater may require special consideration during design and operation of GWHP systems. - Most private wells may be suitable for use as private GWHP systems. - GSHP system water disposal should be available. - Warmer groundwater may be present in unconsolidated sediments at depth, however deep groundwater quality may be an issue.	Moderate to Good	- Mainly coarse grained saturated soil should provide relatively good thermal conductivity. - Good groundwater flow is anticipated.
Ross River	High	- The community well is high yield and is under-utilized. - Community groundwater has a temperature of 5 °C. - The community aquifer is deep (110 m). - Groundwater is, typically, hard and will require careful management for GSHP applications.	Low to Moderate	- Mainly fine grained saturated soil is present, permafrost occurs above 20 m depth. - No shallow bedrock to limit borehole depths.
Teslin	Moderate	- Community well is high yield. - Groundwater temperatures may be too cold for GWHP applications. - Groundwater is, typically, hard. - Identified aquifers are relatively deep.	Moderate	- Soil is mainly saturated glacial till and gravel. - No shallow bedrock to limit borehole depths.

Table I. Summary of GSHP for Rural Yukon Communities

Community	Groundwater Heat Pump (GWHP)		Ground Coupled Heat Pump (GCHP)	
	Potential	Comments	Potential	Comments
Watson Lake	Moderate to High	- Historically, groundwater has been developed extensively for drinking. - Municipal wells are high yield. - Seasonal groundwater temperatures may be too cold for GWHP applications due to surface water influences. - Groundwater may be hard, with elevated iron concentrations.	Moderate	- Soil is mainly saturated glacial tills and gravel. - No shallow bedrock to limit borehole depths.

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Table II. Summary of GSHP Potential for City of Whitehorse

Area	GSHP Type	Potential	Comments
Cowley Creek	GWHP	Moderate to Low	Wells are often deep, low yield and produce water of poor quality.
	GCHP	Low to Good	- Shallow soil mainly varies from unsaturated sands to glacial tills. - Bedrock at surface may allow for completion of boreholes in granite. - Near surface bedrock (e.g. >2 m below surface) may economically limit borehole depths.
Spruce Hill	GWHP	High	High yield aquifer with relatively good water quality at depth represents an exceptionally good opportunity.
	GCHP	Low	Shallow soil is mainly silt and clay.
Mary Lake	GWHP	Moderate to High	- Northern portion of subdivision may have wells completed in basalt, which would be suitable for GWHP applications. - Other portions of the subdivision may contain wells of limited yield, similar to those in the Cowley Creek area.
	GCHP	Low to Moderate	- Shallow soil mainly varies from unsaturated sand and gravel to gravelly till. - Bedrock near surface may economically limit borehole depths.
Wolf Creek / Pineridge	GWHP	High	- Most areas have groundwater supplies adequate to support residential GWHP applications. - Water quality is generally good.
	GCHP	Low to Moderate	- Shallow soil likely varies from unsaturated sand and gravel to gravelly till. - Presence of near-surface bedrock in some areas may economically limit borehole depths.
MacRae	GWHP	High	Most areas have groundwater supplies adequate to support residential GWHP applications.
	GCHP	Low to Moderate	- Shallow soil is mainly fine grained and varies from unsaturated sand and gravel to gravelly till. - Presence of near-surface bedrock in some areas may economically limit borehole depths.
Riverdale	GWHP	High	- The high yield Selkirk Aquifer contains warm groundwater and represents an exceptionally good opportunity. - Many commercial/institutional buildings may be heated using GSHP technology.
	GCHP	Moderate	Shallow soils mainly vary from saturated sand and gravel to saturated fine sand and silt.
Downtown	GWHP	Low	No reported aquifers are suitable to support GWHP systems.
	GCHP	Low to Moderate	- Shallow soil is mainly fine grained (thermal conductivity = 1.07 Btu/hr-ft-degree Fahrenheit). - No near-surface bedrock to limit borehole depths.

Table II. Summary of GSHP Potential for City of Whitehorse

Area	GSHP Type	Potential	Comments
Granger/Copper Ridge	GWHP	Low	No identified significant aquifers are suitable to support GWHP system.
	GCHP	Low	- Shallow soil is mainly unsaturated glacial till. - Near surface bedrock may locally economically limit borehole depths.
McIntyre	GWHP	Moderate	Some groundwater potential is associated with the “Hillcrest Meltwater Channel” and nearby kame delta, however winter groundwater temperatures may be low.
	GCHP	Low to Moderate	Shallow soil mainly varies from sand and gravel to glacial till.
Takhini / Airport	GWHP	Low	No identified aquifers are suitable to support GWHP systems.
	GCHP	Low to Moderate	- Shallow soil is primarily fine grained and may not be saturated. - No bedrock near surface to limit borehole depths.
McIntyre Creek/Yukon College	GWHP	Moderate to High	- Some groundwater development potential, however no recent exploration. - Groundwater temperatures are not documented. - Depth to groundwater in Yukon College area is not identified.
	GCHP	Low to Moderate	- Shallow soil is primarily coarse grained, but may be unsaturated in Yukon College area. - No bedrock near surface to limit borehole depths.
Porter Creek	GWHP	Low to High	- Some areas (e.g. MacDonald Rd.) have good groundwater potential, but drilling may be relatively deep. - Groundwater temperatures and quality are not reported. - Parts of Porter Creek have limited groundwater potential. - Versluce Spring produces good quality warm groundwater.
	GCHP	Low to Moderate	- Shallow soil is primarily coarse grained, but unsaturated. - Locally, near-surface bedrock may economically limit borehole depths.

Table II. Summary of GSHP Potential for City of Whitehorse

Area	GSHP Type	Potential	Comments
Kulan	GWHP	Low	No identified aquifers are suitable to supply GWHP system.
	GCHP	Low to Good	- Where bedrock is at surface, there is a good potential for completion of boreholes in bedrock. - In other areas, of shallow overburden (greater than 2 m in thickness) may limit cost effective borehole drilling.
Crestview	GWHP	Low	No identified aquifers in subdivision area suitable to supply GWHP system.
	GCHP	Low	- Shallow soil is likely coarse grained. - Shallow bedrock in some areas may limit borehole depths.
MacPherson / Hidden Valley	GWHP	Moderate	- Groundwater development for residential purposes seems relatively successful. - Drilling depths may be deep, especially in Hidden Valley area. - Very little is documented regarding well yields or water quality.
	GCHP	Low to moderate	- Shallow soil is primarily fine grained. - No bedrock near surface to limit borehole depths.

Recommendations

The following recommendations are based on the results of our information review. They are listed in order of relative priority, based on potential for development feasibility and level of data confidence:

Whitehorse - Riverdale/Selkirk Aquifer

The high yields and good quality groundwater produced by the Selkirk Aquifer combined with the presence of many schools, apartment complexes and institutional buildings in the Riverdale area provide many potential opportunities for GSHP applications. A feasibility study for a GWHP project at the Vanier School has been completed. The Whitehorse Rapids Fish Hatchery currently uses a heat pump system for heating. There are likely to be additional opportunities for additional development of this resource. However, careful management will be required to protect the municipal water supply aquifer from contamination and ensure that the requirements of all potential users of this resource are met.

Additional GWHP opportunities should be investigated for use at additional schools and institutional buildings in the Riverdale area, including: (a) the Grey Mountain Primary School, (b) implementation of the Vanier School project, (c) the Christ the King Secondary School, (d) offices of the Council for Yukon First Nations, (e) the Selkirk Elementary School and (f) the F.H. Collins Secondary School. The last four potential opportunities are near the City of Whitehorse municipal well field. These GWHP opportunities may be able to be developed cooperatively with the City of Whitehorse. For example, there may be a potential for the return water from GWHPs to be used for heating municipal water.

Mayo

The relatively warm water produced by Mayo's two warm water wells makes the community a candidate for implementation of GWHP technology. Furthermore, this groundwater is currently being used only to heat the municipal water supply via a simple plate exchanger. Heat retained by groundwater that is discharged from the plate exchanger may be suitable for use in a district heating system.

The temperature of discharged municipal groundwater should be measured continuously after it has passed through the plate exchanger. In addition, details regarding the failed community GSHP system should be reviewed and a new feasibility study should be completed, with respect to using the warm groundwater resource in a GWHP system.

Haines Junction

The relatively warm Well No. 5 aquifer is a candidate for exploitation using GWHP technology. ESC should complete its district heating feasibility study and, contingent on a positive study recommendation, initiate heat energy recovery from this ground-thermal resource. In addition, this resource should be carefully managed to maximize the long-term sustainable yield of the well and aquifer.

Carcross

Carcross contains several deep wells that are currently under-utilized due to drinking water quality issues (presence of elevated concentrations of arsenic). These wells include the school well and the old firehall well. There is a potential for a GSHP system for the school to be installed using these two wells, with one well used as a production well and the other as an injection well. The condition of the school and firehall wells should be assessed and a desktop feasibility assessment should be completed for construction of a GWHP system for the Carcross School.

A second potential opportunity exists using groundwater from the existing Government of Yukon (YTG) Highway Maintenance Compound well. This well is reported to yield at rates exceeding 7 L/s and it may be suitable for use in a GSHP system that could be used to heat the Maintenance Compound buildings. The condition of the YTG Highway Maintenance Compound well should be assessed and a desktop study of the feasibility of constructing a GWHP system using the well should be undertaken.

Ross River

The community well is reported to be of high yield and currently appears to be under utilized. Temperatures of groundwater from the well are relatively warm (5 degrees Celsius). A feasibility study should be completed with respect to utilizing the community well aquifer or other deep aquifers for GWHP heating of community buildings.

Carmacks

Development of groundwater appears to be relatively easy in Carmacks. Furthermore, groundwater temperatures do not appear to become too cold for GSHP applications during winter. Therefore, development of GWHP systems may be possible. A feasibility assessment should be undertaken for the installation of a GSHP system for the proposed Carmacks school. Use of GWHP systems should also be considered for heating of other community facilities.

Private wells may have a potential for use in heating homes. However, care must be taken to minimize the potential for fouling of the heat pump equipment due to presence of elevated mineral concentrations in the groundwater. To evaluate the potential applicability of the technology to the residential market, a demonstration home should be equipped with a GSHP system that utilizes groundwater from the home's private well.

Whitehorse General Hospital

The 1980 test well (well TH 2-80) is located 450 m east of the hospital. This well is reported to have a significant yield. However, groundwater from the well contained elevated hardness and/or elevated concentrations of iron and manganese. The presence of this well or aquifer may represent an excellent

GWHP opportunity for the hospital. A feasibility study should be completed to assess the potential for use of GWHP technology at the Whitehorse General Hospital.

Pelly Crossing

Development of groundwater resources appears to be relatively easy in Pelly Crossing. Furthermore, groundwater temperatures do not appear to become too cold for GSHP applications during winter. Accordingly, development of GWHP systems within the community may be attractive. To assess more accurately GWHP potential in the community, continuous temperature monitoring of water from a major community building's well (e.g., the school well) should be conducted to confirm that seasonal groundwater temperature fluctuations are permissive for GSHP development.

Private wells within Pelly Crossing may be suitable for heating homes. However, care should be taken to minimize the potential for fouling of the heat pump equipment. To demonstrate and better assess the potential for use of GSHP technology to residences, a GSHP system should be installed as a pilot project within an existing home.

Whitehorse Multiplex

The expansion of the City of Whitehorse recreational Multiplex on Hamilton Boulevard represents a major GWHP application opportunity. The 1990 test well located at the corner of Hamilton Boulevard and Sumanik Drive may be suitable for this application. Although this well may be too far from the site to be useful, a desktop or preliminary feasibility study should be completed to assess this potential opportunity. This test well should be inspected and groundwater conditions in the aquifer near the well and closer to the Multiplex site should be investigated as the first stage of investigating this potential opportunity.

Watson Lake

The Watson Lake municipal wells are reported to be of high yield. However, the quality of groundwater that is yielded by the wells is poor, with respect to potential use in some GSHP applications. Groundwater development in the community appears to be relatively successful. Seasonal water temperature fluctuations are not reported but temperatures of shallow groundwater during winter may be too cold for year-round operation of GWHPs. Continuous groundwater temperature monitoring should be conducted at the community well to better assess the potential for groundwater in the community aquifer for use in GWHP systems. Careful consideration must also be given to groundwater quality issues when assessing GWHP potential.

Teslin

The community well is reported to have a high yield municipal well. However, the quality of the well's groundwater is poor, with respect to some potential GSHP applications. The potential for seasonal

fluctuation of water temperatures is not documented. There is a potential that winter groundwater temperatures may be too cold for GWHP applications. Groundwater temperature should be continuously monitored at the community well to better assess the potential for GWHP development. In addition, the school well should be inspected and assessed for its potential for use in a GWHP system.

Beaver Creek

Development of groundwater for water supply appears to have been relatively successful. However, little is documented regarding yields and long-term groundwater temperature trends. There appears to be relatively good potential for development of GSHP systems provided that the groundwater temperature is suitable. To further assess the feasibility of GWHP development, continuous groundwater temperature monitoring should be conducted at one or more water wells for the major community buildings, such as at the school well.

Faro

Soil underlying Faro consists mainly of glacial till and glaciolacustrine deposits, which have limited potential to host aquifers. Development of closed-loop (GCHP) systems within Faro is possible. However, the potential for development may be limited by the presence of soil and bedrock with relatively low thermal conductivity characteristics and presence of near surface bedrock in some areas.

It is noteworthy that Faro is currently equipped with an oversized groundwater production and distribution system. There may be potential for this oversized system to be used for a district heating/GSHP scheme. A feasibility study should be completed to review the potential for use of the existing municipal water supply and delivery system for development as a district GSHP heating system. Cold groundwater temperatures in winter may limit the usefulness of the water supply for year-round heating. Groundwater from production wells that are installed farther from the river may be less susceptible to seasonal temperature fluctuations. The temperature of groundwater at municipal wellheads should be continuously monitored to help assess the potential for the municipal groundwater to constitute a GSHP resource.

Whitehorse - Hidden Valley School

Anecdotal accounts suggest that a test well was installed at the Hidden Valley School. Information regarding this test well was not reviewed during this project. The potential for GWHP application at this site should be further assessed. There may be a potential for higher-yield aquifers to exist at depth. Information concerning the Hidden Valley School test well should be obtained, reviewed and evaluated in the context of assessing GWHP potential.

Dawson City

Traditional GSHP development may be difficult in Dawson City. However, more innovative opportunities may exist, such as use of heat pump technology to maintain frozen conditions beneath buildings and utilizing the extracted heat for space heating. An alternative application may be use of pond loops (a variant on the GCHP system) in dredge ponds. Although water in dredge ponds is typically cold, it may represent groundwater flow-through that could be utilized for GSHP systems. ESC should identify innovative opportunities for heat pump technology associated with future developments in Dawson City.

Burwash Landing

There is potential for development of deeper aquifers beneath Burwash Landing at depths of greater than 80 m. Such aquifers may yield groundwater that is not influenced by cold surface temperatures, and that is suitable for use in GSHP systems. Exploration drilling would be required to confirm the potential for presence of deep warm water aquifers beneath the community.

Destruction Bay

Soil underlying Destruction Bay consists mainly of glacial till, which limits the potential for presence of aquifers. Closed-loop (GCHP) systems may be a more viable application. If GSHP opportunities are to be assessed, deeper exploration drilling should be completed to further assess the potential for deep warm aquifers that contain good quality groundwater.

Old Crow

Traditional GSHP development may be difficult in Old Crow. However, innovative opportunities may exist, such as using heat pump technology to maintain frozen permafrost conditions beneath buildings and utilizing the extracted heat for space heating. ESC should identify and investigate innovative uses for heat pump technology for future developments in Old Crow. In addition, continuous monitoring of groundwater temperature at the operating community well should be undertaken to better assess the potential for development of GWHP systems.

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Appendices

- A. Community Profiles
- B. Water Well Database Documentation

1. Project Description and Approach

1.1 Project Objective

Gartner Lee Limited (Gartner Lee) was retained by Energy Solutions Center Inc. (ESC) to catalogue and assess the groundwater and ground-source heat potential for 16 major Yukon communities. Ground-source heat potential refers to the potential for application of groundwater or ground-coupled heat pump technology for space heating. The project objectives were to provide ESC with information that would be suitable for:

- Providing developers, the Government of Yukon (YTG), First Nations and the public with information relevant to developing ground-source heat resources in the Yukon; and
- Creating and populating an accessible electronic database with available water well and groundwater information that would summarize, in a structured format, information concerning groundwater conditions, be suitable for expansion or incorporation into a Territorial water well database and be suitable for use by developers, YTG, First Nations and the general public.

The Yukon communities that were included in this study are as follows (Figure 1.1-1):

Beaver Creek	Keno	Village of Teslin
Burwash Landing	City of Dawson	Pelly Crossing
Destruction Bay	Town of Faro	Town of Watson Lake
Village of Haines Junction	Ross River	Old Crow
City of Whitehorse	Carcross	
Village of Mayo	Village of Carmacks	

1.2 Approach

1.2.1 Existing Information Review

To meet the project objectives, Gartner Lee assembled and reviewed available information from the following principal sources:

- The Department of Indian and Northern Development (DIAND) library in Whitehorse;
- The YTG library in Whitehorse;
- The Yukon Territory Water Board (YTWB) library in Whitehorse;



Site Name: Yukon

File Name: Map_Ref.WOR



Gartner Lee

Scale: 1: 6,000,000

Yukon Groundwater and Ground Heat Potential Inventory

Community Location Map

Project No: 22-680

Date Issued: October 2003

Figure 1.1-1

- Groundwater information that was compiled previously by Intera Environmental Consultants Ltd. (Intera) (1975), Piteau Engineering Ltd. (Piteau) and Integrated Environmental (1989);
- Individual community/municipal libraries; and
- First Nations communities that are located within the above-referenced communities.

Additional sources of historical information that were consulted are identified in Section 5 of this report. The results of terrain analyses that are summarized in this report are based on Gartner Lee's review of aerial photographs that were obtained from the DIAND library in Whitehorse.

1.2.2 Community Visits

A significant component of the project involved Gartner Lee visiting each community except Old Crow, meeting with community representatives and First Nations representatives, soliciting information concerning groundwater issues and observing groundwater conditions at accessible locations. The results of the community visits, including field measurements of groundwater conditions, are summarized in this report. Field investigations included measuring groundwater temperature, electrical conductivity, pH and hardness. Evaluation of these water quality variables is generally useful for assessing the potential suitability of groundwater for use in ground-source heat pump (GSHP) systems.

1.2.3 Water Well Database

Gartner Lee compiled and entered information that appears in the reviewed documents into a relational Microsoft AccessTM database that was created for this project. A copy of the database is provided on the accompanying CD-ROM. Section 3 of this report describes the database structure, format and input parameters. The database contains location data (Universal Transverse Mercator [UTM] coordinates) for all identified wells for which location information could be obtained and, therefore, can be used by geographic information systems (GIS). The well locations and well labeling that are shown on the figures in this report were generated using a GIS directly from the well database.

During spring 2003, ESC purchased approximately 1,000 borehole and water well logs from Midnight Sun Drilling Company Ltd. of Whitehorse (Midnight Sun). Many of the logs are for wells in the communities that were investigated during this project. Some of the logs are for wells at other Yukon locations. Information that is identified on most of these logs has not been reviewed by Gartner Lee and has not been used in preparing the community summaries that appear in this report. Furthermore, these additional logs have not been compiled and entered into the water well database. We understand that ESC intends to organize the logs, compile the information that is identified on the logs and incorporate this information into the water well database. This additional borehole information will assist in assessing groundwater conditions at additional Yukon locations and will provide additional

hydrostratigraphic information for future groundwater assessments. However, this additional information is not expected to significantly change the general assessments that appear in this report.

Information in this report along with the information contained in the accompanying water well database, represents the best summary of readily available Yukon groundwater information that was available in January 2003. It is anticipated that the electronic water well database will be used to form a comprehensive well registry for the Yukon Territory. This information will be key to the sustainable utilization and management of groundwater and ground-source energy resources in the Territory.

1.2.4 Reporting

This report is the final component of the project. The report summarizes identified and inferred groundwater conditions, groundwater resources and factors influencing groundwater occurrence and utilization for each of the 16 Yukon communities that were investigated. Specific emphasis has been placed on groundwater-based heat potential. Information for each community that appears in the report includes:

- a brief physiographic description – the physiographic setting of each community plays a key role in the occurrence and movement of groundwater, earth properties and associated heat-energy potential;
- a climate summary for each community – temperature data provides a general sense of heating-load requirements and precipitation data affects the groundwater recharge potential;
- a geology summary, including a terrain map – this information shows the spatial extent of surficial geological units that potentially host groundwater resources, or that could be utilized in ground-coupled heat pump systems;
- a summary of identified groundwater utilization;
- results of Gartner Lee's community visit, including field measurements of groundwater conditions (e.g., temperature, pH, electrical conductivity, etc.);
- a summary of groundwater quality data – some key parameters that are pertinent to heat pump operation (e.g., potential corrosion, scaling or fouling issues) are summarized; and
- identification of the potential for application of groundwater and ground-coupled heat pump systems, including recommendations regarding priority opportunities and further work that would assist in determining the applicability or potential success of ground-source heat pump technology.

1.3 Ground Source Heat Potential

A key objective of this project was to identify both the physical setting and opportunities for the application of GSHP technology. A GSHP is one of the most efficient means available to heat homes,

offices, schools and community buildings. GSHP systems are sometimes referred to as Earth Energy (EE) or GeoExchange systems.

1.3.1 Technology Description

A GSHP transfers heat energy from under the earth's surface (or in a body of water) into a building. It uses the same principle that is used in refrigeration, where energy is extracted as heat from, for example, food and is discharged by the refrigerator into air. A heat pump extracts energy from its heat energy source (such as low temperature-groundwater) and discharges this heat at higher temperature. The heat pump supplies more heat (equivalent energy) than can alternative uses of the electricity that is used to operate the system.

Use of GSHP technology is desirable because it is environmentally benign, with no associated emissions or harmful exhaust. Although heat pump systems require some electricity to operate, the heat pump's high efficiency (sometimes as high as 400 per cent) results in GSHP systems reducing levels of heating-associated carbon dioxide, sulfur dioxide and nitrous oxide emissions, all of which have been linked to greenhouse gas emissions and global warming.

Currently, the two primary types of GSHP systems are:

1. **Groundwater Heat Pumps (GWHPs) – commonly known as open-loop heat pumps.** These systems pump groundwater from an aquifer, extract the heat energy from the water, and dispose of the cooler water to the ground surface or return it to the aquifer using injection wells. GWHP systems are the most efficient and cost effective type of GSHPs, but require groundwater of suitable temperature and quality to be effective. Low groundwater temperatures reduce the GWHP efficiency and are at risk for causing freezing of the water discharge system. Groundwater quality issues (e.g., corrosion, scaling or fouling), if not carefully managed, may lead to failure of GWHP systems.
2. **Ground-Coupled Heat Pumps (GCHPs) – commonly known as closed-loop heat pumps.** These systems consist of a water or water-antifreeze solution which is passed through a network of U-shaped tubes which are installed within vertical boreholes. Heat from the subsurface is conducted through the tubes into the liquid solution, which is then pumped to surface and extracted using a heat pump. Efficiency of GCHP systems is lower than GWHP systems and they are more costly to build. However, they do not require a high yield aquifer and can be used in most settings. GCHP efficiency is primarily dictated by the thermal properties of soil hosting the system.

For general information concerning heat pump technology, the reader is referred to the Earth Energy Society of Canada (www.earthenergy.ca) or the International Ground Source Heat Pump Association (www.igshpa.okstate.edu). Detailed information of the design and operation of GSHP systems is

provided by the American Society of Heating, Refrigeration and Air-Conditioning Engineer's publication "Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings" (Kavanaugh and Rafferty 1997).

1.3.2 GSHP Criteria

For each investigated community, the relative potential for application of GSHP technology has been assessed according to the following qualitative criteria:

Groundwater Heat Pump (GWHP) Application Potential	
High	Adequate well yields suitable for residential GWHP application, good water quality
Moderate	Adequate well yields for residential GWHP application, however deep drilling may be required or water quality issues may be present. Groundwater may be influenced by surface water and therefore winter groundwater temperatures may be low.
Low	Insufficient groundwater potential to support GWHP applications

Ground Coupled Heat Pump (GCHP) Application Potential*	
Good	Soil and/or rock with typical thermal conductivity values greater than 2.0 Btu/h·°F·ft**, uniform drilling conditions to at least 60 m depth (e.g. no changes from unconsolidated sediments to bedrock), and/or good groundwater flow
Moderate	Soil with typical thermal conductivity ranging from 0.8 to 2.0 Btu/h·°F·ft, uniform drilling conditions to at least 30 m depth and/or limited groundwater flow
Low	Soil with typical thermal conductivity values ranging from 0.2 to 0.8 Btu/h·°F·ft, uniform drilling conditions for less than 30 m depth, no significant groundwater flow

*GCHP systems are applicable to most locations. The identified ranking scheme is a relative ranking based on anticipated system efficiency and capital cost effectiveness.

** Most heat pump systems are designed using US units.

Permafrost or near-freezing ground temperature occurs beneath many Yukon communities. It is common for GCHP systems to operate at sub-zero temperatures using an anti-freeze solution that is circulated through the closed-loop system. However, how these low temperature conditions effect the efficiency of these systems is currently not well understood. Significant heat may be generated by the phase change from subsurface liquid water to ice. Furthermore, ice provides excellent thermal contact for thermal transfer to and from the borehole loop. However, the long-term benefits and potential issues associated with operating GSHPs under such conditions are not well documented.

2. Methodology

2.1 Background Information and Community Visits

Gartner Lee reviewed as much available information as was practical before visiting the communities in December 2002 and January 2003. Gartner Lee reviewed additional information after the visits. Data sources are listed in Section 5 of the report.

Gartner Lee visited 15 of the 16 communities covered by this report between December 2002 and January 2003 (Old Crow was not visited due to prohibitive travel costs). The purpose of the visits was to: (a) meet with community members, officials and First Nations representatives, (b) solicit and gather information concerning groundwater conditions that is not on file at the DIAND, YTG, and YTWB Whitehorse libraries; (c) measure groundwater conditions in accessible wells; and (d) identify potential issues and concerns associated with groundwater. During the visits, Gartner Lee identified selected well locations using a handheld global positioning system (GPS) instrument. Information gathered during the community visits was entered in the water well inventory database.

2.2 Terrain Interpretation

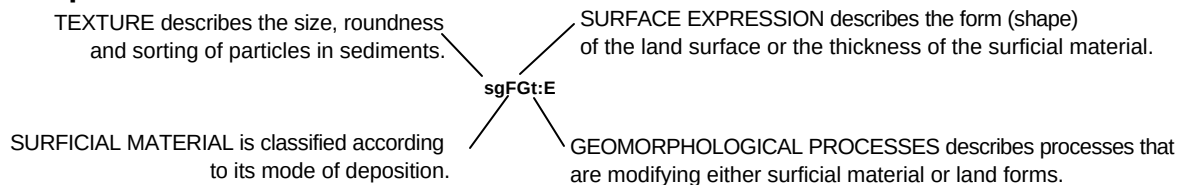
Gartner Lee generated a terrain map for each community by interpreting stereo aerial photographs. The main purpose of the terrain analysis was to map the inferred distributions of surficial soil conditions near the communities. The results of the analyses provide context for the assessments of groundwater and ground-source heat potential that appear in the report. Specifically, identifying the distributions of inferred surficial materials helps identify both the potential lateral extents of near-surface aquifer materials that are identified in water well records, as well as additional potential areas for groundwater development. Thermal conductivity, which is controlled in part by soil type, is a key parameter that is used to design GCHP systems. Inferences concerning the distributions of different soil types near the communities may, therefore, assist in the design or siting of GCHP systems.

A terrain map based on Gartner Lee's interpretation of aerial photographs accompanies each community description. Gartner Lee used aerial photographs with nominal scales ranging from 1:20,000 to 1:40,000 for the analysis. Gartner Lee digitized line work (such as soil-polygon boundaries) from the interpreted photographs into a GIS to produce the terrain maps. Each terrain area or "polygon" is associated with a label listing the inferred soil texture (if known), the inferred genesis of the surficial material, landform(s) and applicable geomorphic processes. The legend that applies to the terrain maps appears in Figure 2.2-1. Up to three types of surficial materials for each soil polygon, including subsurface or underlying materials

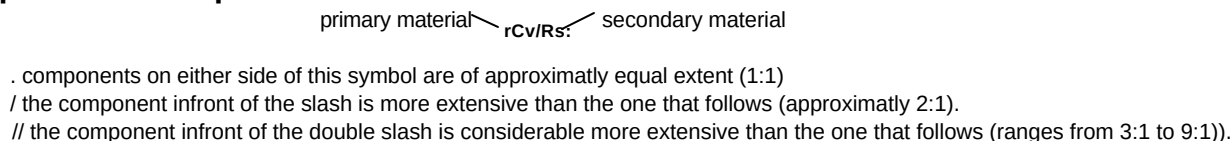


TERRAIN MAP LEGEND

Simple Map Unit:

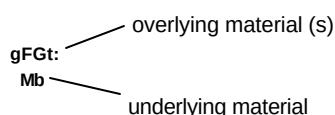


Complex/Mixed Map Unit:



Stratigraphic Map Unit:

Materials



O	ORGANIC DEPOSITS deposits vary from fibric to humic, are usually thinner than 0.5 m.
E	EOLIAN DEPOSITS usually consists of fine sand with minor silt; landform surface is hummocky (dunes).
EA	EOLIAN DEPOSITS, ACTIVE active sand dunes and dune fields.
C	COLLUVIAL DEPOSITS usually mixed material, from silt to boulder size, usually found on slopes steeper than 20%
F	FLUVIAL DEPOSITS includes silt to gravel sized material.
FA	FLUVIAL DEPOSITS, ACTIVE active fluvial plains (e.g. flood plains)
GL	GLACIOLACUSTRINE DEPOSITS usually consists of fine sand and silt with minor clay (less than 10%) and occasional sandy to gravelly pockets.
FG	GLACIOFLUVIAL DEPOSITS usually consists of well graded sand and gravel- varies from deposit to deposit. It is common to find a silt and/or sand veneer over the gravelly sediment.
M	MORAINAL DEPOSITS usually consists of pebbly to bouldery gravel with a silty, sandy matrix. Clay content in matrix is low. Matrix at depth (greater than 1 m) is usually rich in carbonates.
R	BEDROCK : variable. In some areas, the bedrock consists of altered granite or gneiss and can behave like a poorly graded pebbly gravel with low matrix content
A	ANTHROPOGENIC Gravel pit, road, airport developed area, mine or other surfaces modified by people.

Textural Component

b - boulders
 c - clay
 g - gravel
 s - sand
 z - silt

Landforms

a - moderate slope
 b - blanket (>1m)
 f - fan(s)
 h - hummocky
 j - gentle slope
 k - moderately steep slope
 m - rolling topography
 p - plain
 s - steep slope
 t - terrace(s)
 u - undulating topography
 v - veneer (<1m)
 x - thin veneer (<0.2m)

Geomorphological Processes

EROSIONAL PROCESSES	PERIGLACIAL PROCESSES
D - deflation	X - Permafrost processes
V - gully erosion	Xt - Thermokarst
W - washing	
FLUVIAL PROCESSES	DEGLACIAL PROCESSES
I - irregularly sinuous channel	E - channelled by meltwater
J - anastomosing channel	H - kettled
M - Meandering channel	
U - inundation	

Site Name: Yukon

File Name: TERRAIN_MAP.WOR



Gartner Lee

Yukon Groundwater and Ground Source Heat Potential Inventory

Terrain Map Legend

Project No: 22-680

Date Issued: Oct 2003

Figure 2.2-1

are identified. Gartner Lee verified terrain interpretations by comparing the interpreted information with information identified in drilling records. However, no field verification of the interpretations was completed. The terrain interpretation follows the Terrain Classification System for British Columbia (Howes and Kenk 1997). Details regarding terrain mapping and interpretation are provided in Howes and Kenk (1997) and the document “*A User’s Guide to Terrain Maps in British Columbia*” (Ryder and Howes), found at: <http://srmwww.gov.bc.ca/rib/wis/terrain/publications/guide/>

2.3 Field Measurements

2.3.1 Well Location

Locations of community wells that were inspected by Gartner Lee were determined using a Garmin Etrex Summit handheld GPS instrument or with reference to local landmarks. The horizontal accuracy of the GPS instrument is, on average, between 8 m and 12 m. No vertical (elevation) component was recorded using the GPS instrument. When possible, well locations were measured at the well head. In cases where the exact location of the well could not be determined or the well head was not accessible, the location was measured adjacent to the pump house or near the corner of a building near the suspected location. Accuracy information is identified for each well location in the water well database.

2.3.2 Groundwater Sampling Locations

Whenever possible, Gartner Lee measured groundwater field parameters at the well head. In many cases, however, the well head was not accessible. In such situations, Gartner Lee measured groundwater quality from the nearest available sampling point to the well and, if possible, before the water was treated or entered a reservoir or distribution system. Wherever possible, groundwater was allowed to flow for a minimum of five minutes or until the stagnant water had been purged from the distribution system and fresh well water was being pumped directly to the sampling point. In many cases, the water was allowed to flow for between 15 minutes and 20 minutes before the pH or electrical conductivity measurements had stabilized.

2.3.3 Measurement of Groundwater Temperature, pH and Electrical Conductivity

Gartner Lee measured groundwater temperature using a Hannah model pHep 5 handheld combination pH and temperature probe. Temperature measurements are accurate to within 0.1 degrees Celsius. Water pH measurements are accurate to 0.1 pH unit. The pH probe was calibrated daily and was checked routinely as sampling progressed. Groundwater temperature and electrical conductivity were measured using a YSI model 30 combination electrical conductivity and temperature probe. The instrument is equipped with an

automatic temperature-calibration feature for measuring electrical conductivity. Electrical conductivity may be used to estimate the relative amount of dissolved constituents (ions) in water. Heavily mineralized or ion-rich water (e.g., saline water) generally has a relatively higher electrical conductivity.

2.3.4 Measurement of Groundwater Hardness

An important variable to consider when designing GWHP systems is the amount of dissolved constituents in the water. Geochemical changes that may occur during the heat exchange process may lead to precipitation of dissolved constituents and accumulations of scale within the system.

Gartner Lee measured groundwater hardness in the field using Softcheck test strips from Hach. This method of monitoring water hardness was used because it is fast and provides a level of accuracy that is adequate for this application. Hardness ranges that are indicated by the test strips are:

- “Soft” - 0 parts per million (ppm) to 25 ppm;
- “Moderate Hard” - 25 ppm to 50 ppm;
- “Hard” - 50 ppm to 120 ppm; and
- “Very Hard” 120 ppm to 250 ppm and 250 ppm to 425 ppm.

A discussion of groundwater quality parameters and issues associated with fouling and/or corrosion of GSHP systems is found in Kavanaugh and Rafferty’s *“Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings”* (1997).

3. Database Structure

A major component of the project involved the development of an electronic water well database. The accompanying CD-ROM includes the database that Gartner Lee developed for this project. The database (*YTGW.mdb*) is a relational database that was created using Microsoft AccessTM 2000 (MS-Access). MS-Access is currently the most widely available and widely supported commercial database software. MS-Access databases can be read into spreadsheets, desktop mapping software (such as MapInfo or ArcView), GISs and groundwater modelling pre/post processors such as ViewLog.

3.1.1 Data Model

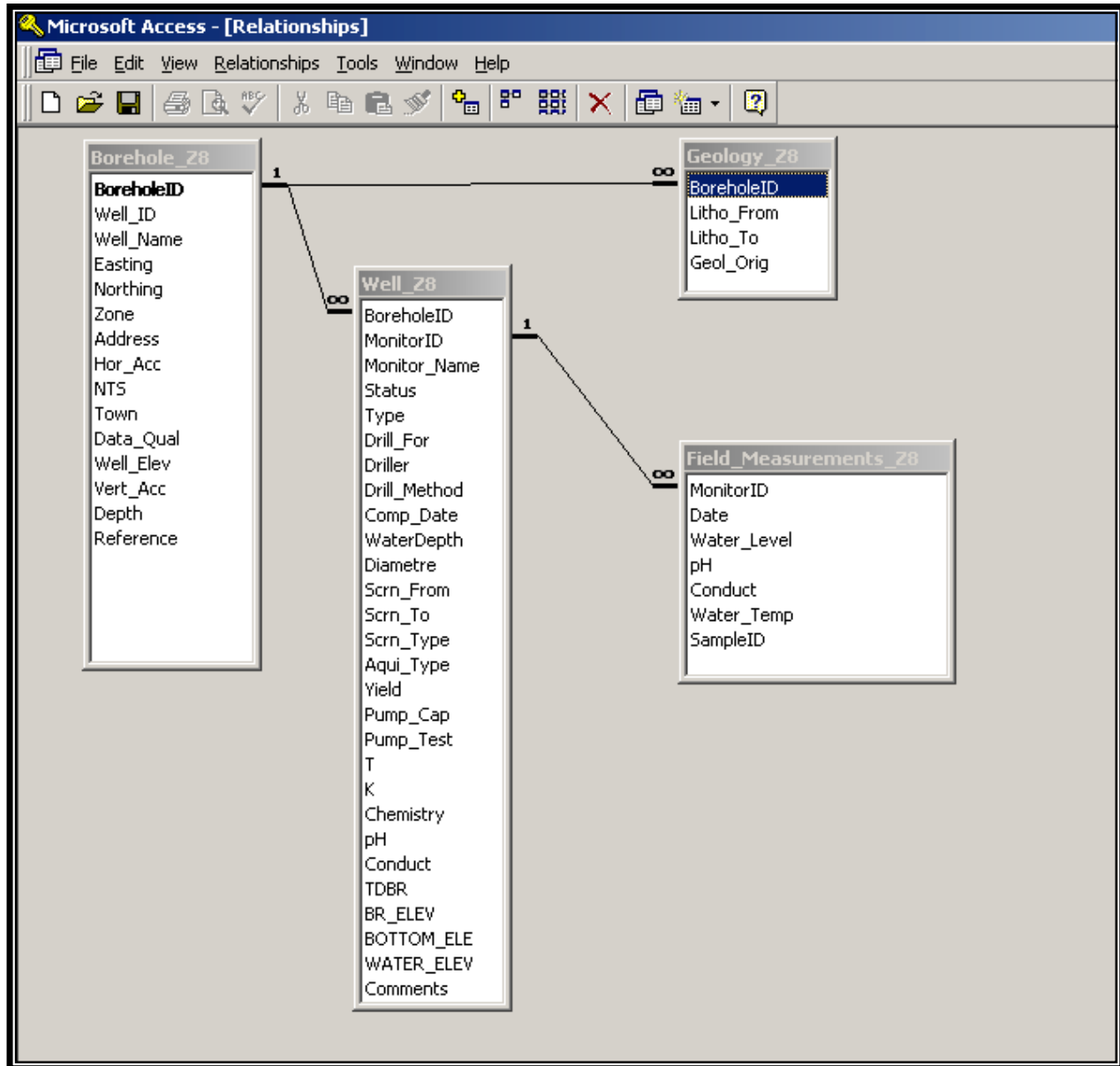
Water well database development for this project is an expansion of a "flat" water well database that Gartner Lee developed for the Wolf Creek-Pineridge area (Gartner Lee 2001) to a fully relational database. This allows unlimited expandability to the database and significant flexibility. An orthogonal data model is used that allows one-to-many relationships. The database structure is illustrated in Figure 2.3-1.

The data model that was used for this project is widely used in Canadian well databases and is similar to the existing B.C. and Ontario provincial water well databases. This data design follows the EarthFX data model that is currently used for most of the Ontario Oak Ridges Moraine hydrogeological assessment projects. The database design is also consistent with the Federal Provincial Groundwater Working Group's Guidelines for Groundwater Data Management (1991). However, the proposed scope and extent of the database is significantly simpler and more limited than the above-mentioned databases. Because the database is open and flexible, the database lends itself to increased complexity over time, as needed.

This database structure consists of four primary tables:

1. **Borehole** – A borehole location table, each location receives a unique identifier (BoreholeID) in this primary table.
2. **Well** – Well construction, usage and other aquifer details. A one-to-many relationship with the Borehole table (via the BoreholeID) allows multiple wells per borehole. Multiple level monitoring wells are frequently used in environmental investigations.
3. **Geology** – Stratigraphic information encountered during borehole drilling. The one-to-many relationship with the Borehole table (via the BoreholeID) allows unlimited Stratigraphic intervals at each.

Figure 2.3-1 Water Well Database Model



Yukon Groundwater and Ground Source Heat Potential Inventory

4. **Field_Measurements** – Basic field measurement data include water level and groundwater temperature data. A one-to-many relationship with the Well table (via the MonitorID) allows multiple measurements over time (e.g., changes in water temperature or level over multiple years).

The database includes ancillary tables used for report references and look-up tables to standardize data entry. The database is fully documented and commented internally. Complete documentation is provided in Appendix B. All borehole data is referenced by UTM (NAD83) co-ordinates. The UTM coordinate system is used for the following reasons:

- it is metres-based (rather than being based on degrees of longitude and latitude, which are not readily measurable on the ground);
- most hand-held GPS units can identify UTM co-ordinates; and
- site-specific maps produced in the UTM system have minimal associated distortion.

As with any digital data, the concept of “garbage-in, garbage-out” applies. Some of the digital data QA/QC measures that have been incorporated into the database include:

- extensive use of data-validation rules, mandatory data fields, and code tables during data entry; and
- use of data-quality terms, including provision of general data completeness fields and mandatory horizontal and vertical accuracy codes.

Database tables and fields are as follows:

Table 2.3-1 Water Well Database Fields

Field	Description	Reference (Lookup) Table
Borehole – General site information, location, total depth, etc.		
BoreholeID	Unique borehole identifier (see Appendix B for discussion of BoreholeID numbering system)	
Well ID	Old well ID from previous reports/databases	
Well Name	Local, or recent reference name of well	
Easting	UTM Easting Coordinate (NAD83)	
Northing	UTM Northing Coordinate (NAD83)	
Zone	UTM Zone (zone 7-10 for Yukon)	
Address	General street address	
Hor_acc	Horizontal accuracy code	R_Hor_acc
NTS	1:50,000 NTS topographic mapsheet number	
Town	Name of town or community well is located in.	R_Town
Data_Qual	Data quality / completeness field (good, fair, or poor)	R_Data_Qual
Well_Elev	Well head elevation (m ASL)	
Vert_acc	Vertical (elevation) accuracy code	R_Vert_Acc
Depth	Total <i>borehole</i> depth (in metres)	
Status	Usage status of well	R_Status

Yukon Groundwater and Ground Source Heat Potential Inventory

Field	Description	Reference (Lookup) Table
Type	Purpose of well	R_Type
Drill_For	Person or agency well was drilled for	
Driller	Drilling company code	R_Driller
Comp_Date	Well completion data completion date of deepening	
Reference	Report reference/data source	R_Reference
Well – Well construction details (multiple wells allowed per borehole, e.g., multi-level environmental monitor wells)		
Borehole ID	Links well to borehole table	
MonitorID	Unique well (monitor) identify	
Monitor_Name	Name of well or monitor (allows unique names for multiple monitors per location)	
WaterDepth	Initial depth to static water level (in meters from ground surface)	
Diameter	Well diameter (in centimeters)	
Scrn_From	Depth to top of screen (in metres)	
Scrn_To	Depth to bottom of screen (in metres)	
Scrn_type	General description of well screen type	
Yield	Estimate of well yield (in L/s) – either calculated long-term yield from pumping test or driller's estimate	
Pump_cap	Installed pump capacity (in L/s)	
Pump_Test	Date of pump test (if conducted)	
T	Reported transmissivity (m ² /day) – use best value if multiple estimates	
K	Reported hydraulic conductivity (m/s) – use best or mean value if multiple estimates.	
Chemistry	Chemical analysis available? (Yes/No)	
pH	Initial reported water pH	
Conduct	Initial reported water electrical conductivity (µmhos/cm)	
Comments	Misc. comments for other notes	
Geology – Geological materials reported in drilling record		
BoreholeID	Links well to Borehole table	
Litho_From	Depth from surface to top of lithologic interval	
Litho_To	Depth from surface to bottom of lithologic interval	
Geol_Orig	Geological material description as originally reported in drilling record	
Field Measurements – Water level, temperature, pH and other field data (collected on multiple dates)		
Monitor ID	Links measurement to Well table	
SampleID	Identifier assigned to water sample, if collected	
Date	Date of field measurement	
Water_Level	Depth to water (m below top of casing)	
Stickup	Height above ground of riser pipe (or inner casing), in metres (this may change overtime if well is damaged)	
pH	Field measurement of water pH	
Conduct	Field measurement of water electrical conductivity (µmhos/cm)	
Reference	General report reference, if published	

4. Community Groundwater Summary

4.1 Beaver Creek

1.1.1 Beaver Creek Community Description

Beaver Creek is located at Mile 1,202 of the Alaska Highway approximately 300 km northwest of Haines Junction and several kilometers from the Alaska border (to the west). The community is located on the Kluane Plateau between mountains of the Dawson Range (to the north) and mountains of the Nutzotin Range (to the south). A location map that shows Beaver Creek and surrounding topography is shown in Figure 4.1-1. A community profile of Beaver Creek appears in Appendix A.

The area near Beaver Creek was first settled in the 1910s as a supply depot between the White River and the Chisana goldfields. The community was first developed as a Canadian Customs post in 1950. Beaver Creek was and continues to be a border post and a maintenance centre for the Alaska Highway. The population of Beaver Creek is 111 (Yukon Bureau of Statistics 2003). The community is located within the traditional hunting and trapping area of the Upper Tanana people and is home to the White River First Nation (WRFN). Electricity for Beaver Creek is supplied by diesel generators.

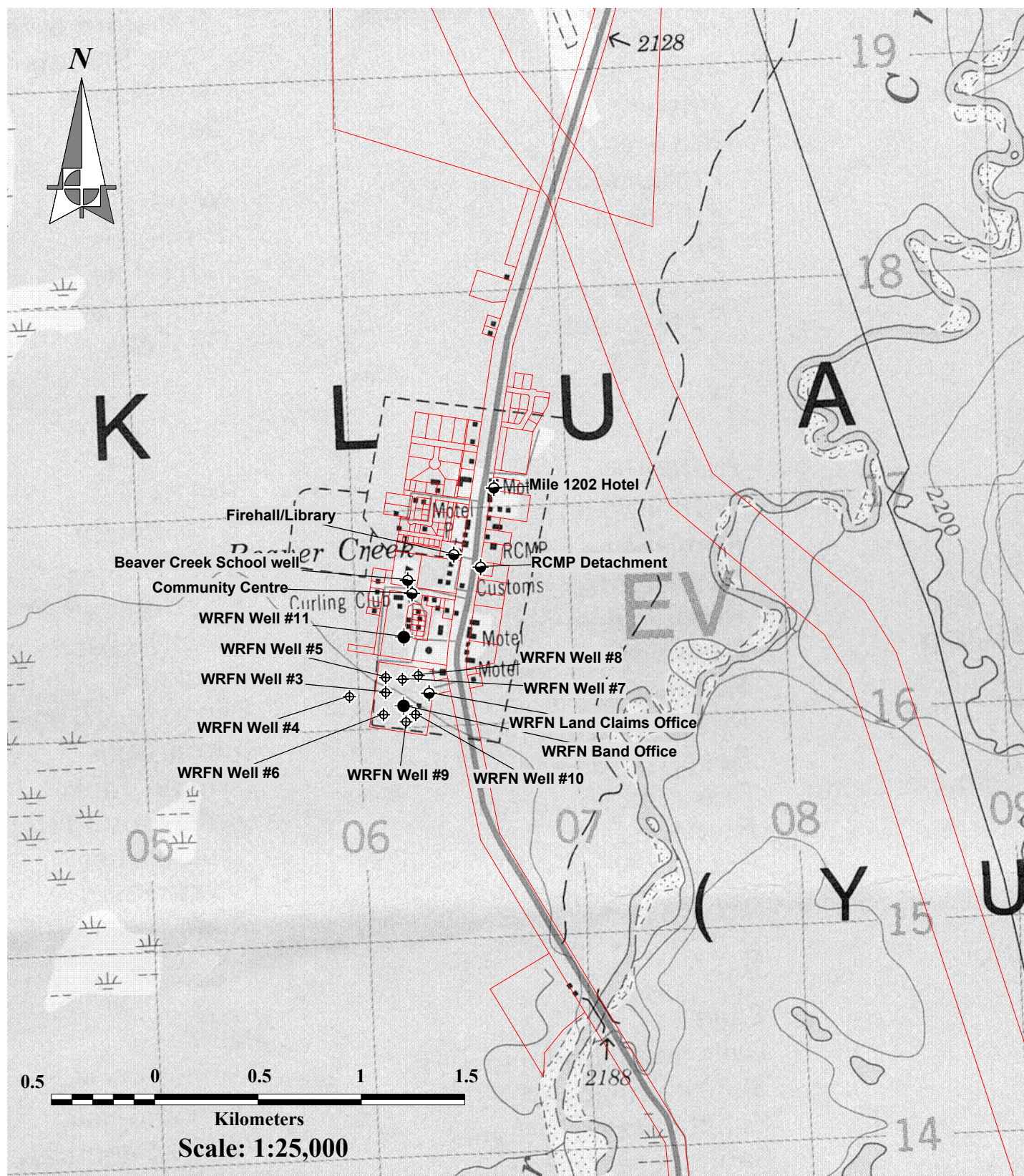
4.1.2 Beaver Creek Climate

Climate normal data for Beaver Creek, based on the period 1997 to 2002, are summarized in Table 4.1-1.

Table 4.1-1 Climate Normals for Beaver Creek, 1997-2002

Month	Mean Temperatures – Beaver Creek (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-20.20	-30.60	-25.18	16.64
February	-12.33	-20.15	-20.87	13.24
March	-2.23	-15.62	-12.23	13.46
April	6.34	-6.06	-0.37	12.2
May	12.40	-0.55	5.74	43.62
June	19.54	5.16	12.98	75.6
July	20.38	6.55	14.20	112.7
August	17.48	3.92	11.22	73
September	11.44	-0.62	5.14	53.62
October	-1.73	-10.02	-6.93	36.16
November	-14.43	-17.94	-19.53	14.34
December	-19.37	-28.57	-25.17	14.08
Year	1.44	-9.54	-5.08	478.66

Source: Environment Canada 2002.



LEGEND:

Identified Water Well Locations
(number of wells)

- ⊕ Commercial/Institutional (6)
- ⊕ Domestic (8)
- Municipal/Communal (2)

Source of Drawing:
Energy, Mines and Resources Canada,
1981. National Topographic Series 115 K/07

Reviewed By: FKP

Drawn By: GC

Revised: October, 2003

Project Number: 22-680

File Name: 22680_bcreek_fig1_Final.WOR

Revision: 0

**Beaver Creek
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Gartner Lee

Figure No.

4.1-1

4.1.3 Beaver Creek Topography and Hydrology

The elevation of Beaver Creek is approximately 665 m above mean sea level (amsl). The community is approximately 1 km west of Beaver Creek (the eponymous surface water body) and 4 km west of Macauley Ridge. Eikland Mountain (elevation 1,341 m amsl), approximately 10 km to the south, is the highest nearby mountain. The community lies in an area of rolling plain and muskeg terrain near the confluence of Beaver Creek and Snag Creek. Areas of swamp and muskeg occur south, west and north of the community. Topography near Beaver Creek along with identified well locations are shown on Figure 4.1-1.

4.1.4 Beaver Creek Geology

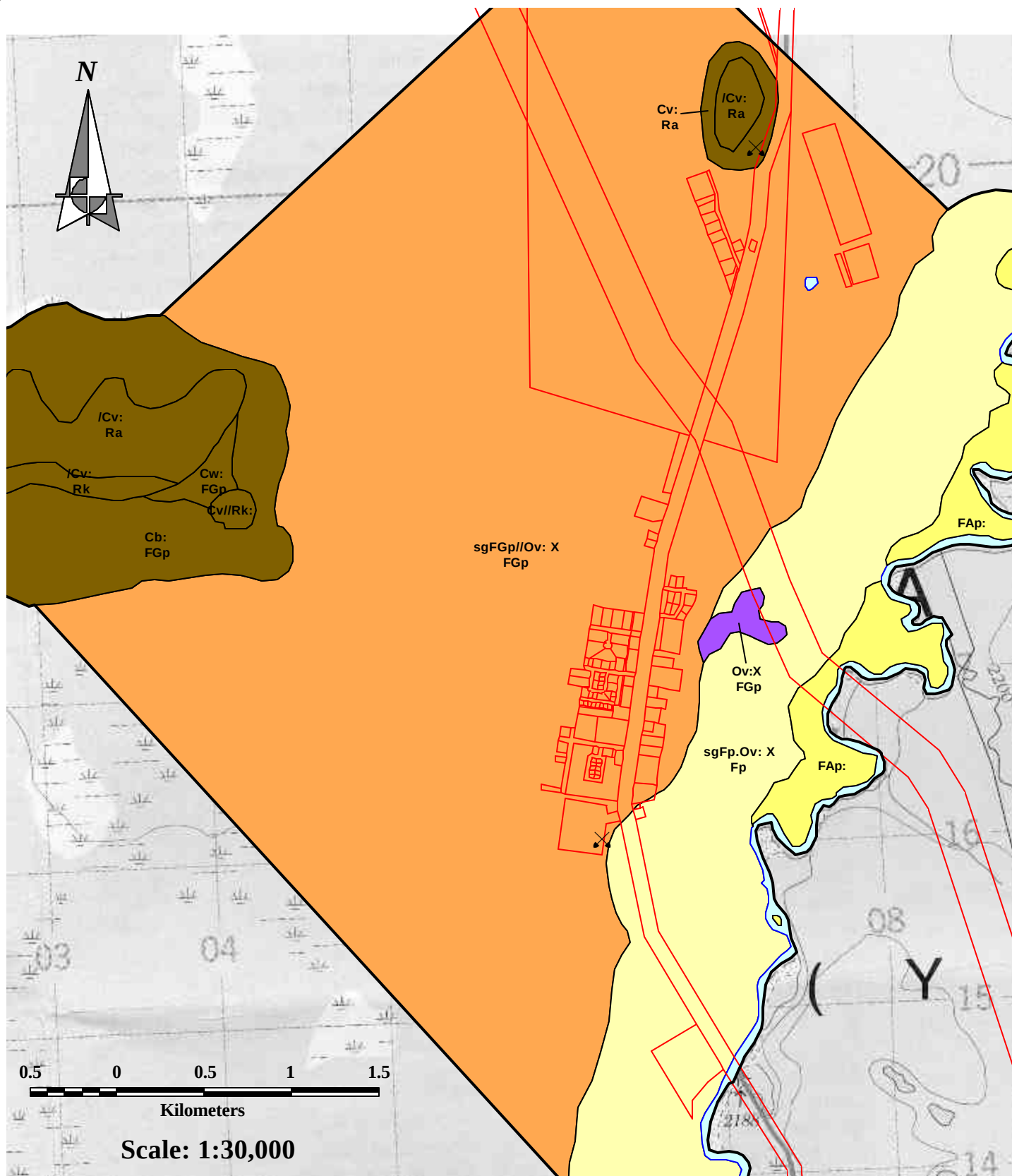
The most recent published surficial geology mapping of the Beaver Creek area is by Rampton (1978). The results of the terrain analysis completed as part of this project for the Beaver Creek area are shown on Figure 4.1-2.

Beaver Creek is located on a broad glaciofluvial plain. The inactive and active flood plains of Beaver Creek are east of the community. Soil within these areas is anticipated to consist mainly of sand and gravel. Some areas near the community contain a veneer (up to 1 m thick) of organic soils. Intera (1975) reported that some developed sand and gravel aquifers beneath the community occur at depths of between 18 m and 34 m. Most of the area near Beaver Creek is underlain by continuous permafrost, which is reported to extend to depths of 25 m to 60 m (David Nairne & Associates 1989).

Bedrock that is exposed on a knoll that is north of town has been identified as interbedded argillite, cherty slate and quartzite of the Windy oceanic assemblage (Gordey and Makepeace 2000).

4.1.5 Beaver Creek Hydrogeology

Locations of identified water wells in Beaver Creek are shown on Figure 4.1-1. Most identified wells are completed between depths of 15 m and 30 m. It is our understanding that most wells in the community are heat traced to minimize the potential for freezing. The direction of groundwater flow near the community is not known to Gartner Lee. It is anticipated, however, that the unconsolidated glaciofluvial sediments that underlie the community host a complex system of confined aquifers beneath or within the (discontinuous) permafrost zone.



LEGEND:

Primary Surficial Material

- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- FG - Glaciofluvial
- O - Organic

Extent of terrain mapping

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Drawing:
Energy, Mines and Resources Canada,
1981 National Topographic Series 115 K/07
Reviewed By: FKP
Drawn By: NS/FKP
Revised: June 2003
Project Number: 22-680
File Name: 22680_bcreek_surfgeo.WOR
Revision: 0

**Beaver Creek
Terrain Analysis**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.1-2**

Intera (1975) reported that a shallow aquifer that historically supplied water to the Customs Office and several nearby houses was abandoned due to contamination from spilled fuel. Intera also reported that some community wells were contaminated with nitrate, likely from septic fields.

4.1.6 Beaver Creek Community Visit

Gartner Lee visited Beaver Creek on December 9, 2003. During this visit, Messrs. Martin Guilbeault and Dennis Lu of Gartner Lee visited the following individuals and locations:

- Mr. Charlie Eikland of WRFN. Mr. Eikland provided information regarding WRFN community wells.
- Mr. Dennis Larkin, a resident of Beaver Creek. Mr. Larkin is familiar with the operation and maintenance of WRFN wells. Mr. Larkin provided access to pump houses and houses where Gartner Lee measured groundwater field parameters.
- The Beaver Creek School
- Constable Ray Warner of the Beaver Creek Royal Canadian Mounted Police (RCMP) detachment. Constable Warner provided access to detachment groundwater and identified the detachment reservoirs.
- The Beaver Creek Library and Firehall.
- The Mile 1202 Motel. Field measurements were taken from a tap in the main kitchen.
- The Beaver Creek Community Centre. Groundwater field measurements were made at a tap in the men's washroom.
- Mr. Beat Ledergerber. After the visit, Mr. Ledergerber provided information concerning locations, depths and construction details for Beaver Creek wells.

The above-referenced locations are shown on Figure 4.1-1. Results of groundwater field measurements by Gartner Lee on December 9, 2002 are summarized in Table 4.1-2.

Table 4.1-2 Beaver Creek Groundwater Field Parameters Measured on December 9, 2002

Location	Temperature (°C) ^b	pH	Electrical Conductivity (µS)	Hardness	Comments
Mile 1202 Hotel	6.7	7.6	284	Very hard	
RCMP detachment	3.4 ^a	7.5	427	Very hard	At front of building
WRFN Band Office	6.3	7.7	308	Very hard	
WRFN Land Claims Office	7.1	7.6	309	Hard	Supplies 2 trailers
WRFN Well No. 3	6.4	7.7	287	Very hard	Supplies 2 houses
WRFN Well No. 4	6.4	7.4	289	Very hard	Vacant new house Supplies 2 houses
WRFN Well No. 5	3.0	7.8	287	Hard	Supplies 2 houses (Charlie Eikland)
WRFN Well No. 6	3.5	7.7	295	Hard	Supplies 2 houses
WRFN Well No. 7	7.3	7.5	309	Very hard	Vacant trailer
WRFN Well No. 8	-	-	-	-	Not sampled Supplies 2 houses
WRFN Well No. 9	-	-	-	-	Not sampled Supplies 2 houses
WRFN Well No. 10	-	-	-	-	Not sampled Supplies one house
WRFN Well No. 11	-	-	-	-	Community well Supplies 6 houses
Community Centre	4.0	7.3	357	Very hard	
Beaver Creek School	4.0	7.1	325	Hard	
Library/Firehall	10.2	7.7	366	N/A	Large storage tank

^a Reservoirs are located outdoors.

^b Gartner Lee was informed that some WRFN wells are heat-traced, which could influence temperature measurements

4.1.7 Beaver Creek Private Water Supply

Residents of Beaver Creek obtain water from private wells. According to discussions with community members (Beat Ledergerber, pers. comm., 2003), at least 50 private wells have been installed within the community. In addition, WRFN has installed ten private wells, nine of which service one or two houses and one which services six houses. It is reported that some private wells required deepening by between 3 m and 5 m following the 1964 Alaska Earthquake. Gartner Lee is not aware if any residents within Beaver Creek use trucked water delivery.

4.1.8 Quality of Groundwater in Beaver Creek

Gartner Lee identified minimal historical information concerning the quality of groundwater in Beaver Creek. Groundwater from the WRFN community wells was analyzed by Gartner Lee in 2002 (Gartner Lee 2002a). A summary of available water quality data that are relevant to GWHP systems is presented in Table 4.1-3.

Table 4.1-3 Selected Characteristics of Beaver Creek Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Manganese (mg/L)	Reference
Customs Office (July 1961)	8.0	252	-	0.09	0.03	Intera (1975)
Ida's Motel (July 1961)	8.0	411		0.08	0.5	Intera (1975)
WRFN subdivision	8.17	202	164	< 0.03	< 0.002	Gartner Lee 2002a
WRFN Band Office	8.2	167	137	< 0.03	< 0.002	Gartner Lee 2002a

4.1.9 Beaver Creek GSHP Potential

GSHP Type	Potential	Comments
GWHP	Moderate to High	- Development of groundwater seems to be relatively successful, however long-term groundwater temperatures are not known to Gartner Lee - Water quality for GWHP appears to be relatively good, however water can be hard. - Some wells contained heat trace taping and therefore groundwater temperatures are likely lower than those measured during the community visits
GCHP	Moderate	- Subsurface soils are likely saturated sand and gravel. - Impact of permafrost presence in this community on GCHP long-term efficiency is not identified. - Depth to bedrock is not identified, may potentially be within 30 m of surface.

Historically, development of groundwater resources in Beaver Creek appears to have been relatively successful, based on the large number of operating wells. However, little is documented concerning the well yields and long-term groundwater temperature trends. There appears to be relatively good potential for use of GSHP systems in this community, provided that the groundwater is of suitable temperature.

To further assess the potential for use of GWHP applications for this community, *it is recommended that groundwater temperature be monitored on a long-term continuous basis at one or more of the major community building water-supply wells (e.g., the school well).*

4.2 Burwash Landing

4.2.1 Burwash Landing Community Description

Burwash Landing is located in the Shakwak Valley along the west shore of Kluane Lake. The community is adjacent to the Alaska Highway approximately 285 km from Whitehorse and 127 km northwest of Haines Junction. Mountains of the Kluane Range rise to the west. A location map that shows Burwash Landing, Kluane Lake and the surrounding topography along with identified water well locations is shown in Figure 4.2-1. A community profile of Burwash Landing appears in Appendix A.

Burwash Landing is within the traditional territory of the Kluane First Nation (KFN). The community was developed as a traditional summer campsite and eventually became an administrative center for the Kluane area during construction of the Alaska Highway. The population of Burwash Landing is 78 (Yukon Bureau of Statistics 2003). Electricity for the community is supplied by diesel generators that are located in Destruction Bay.

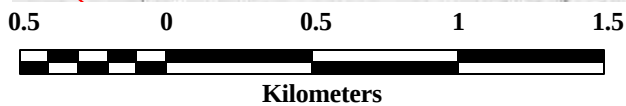
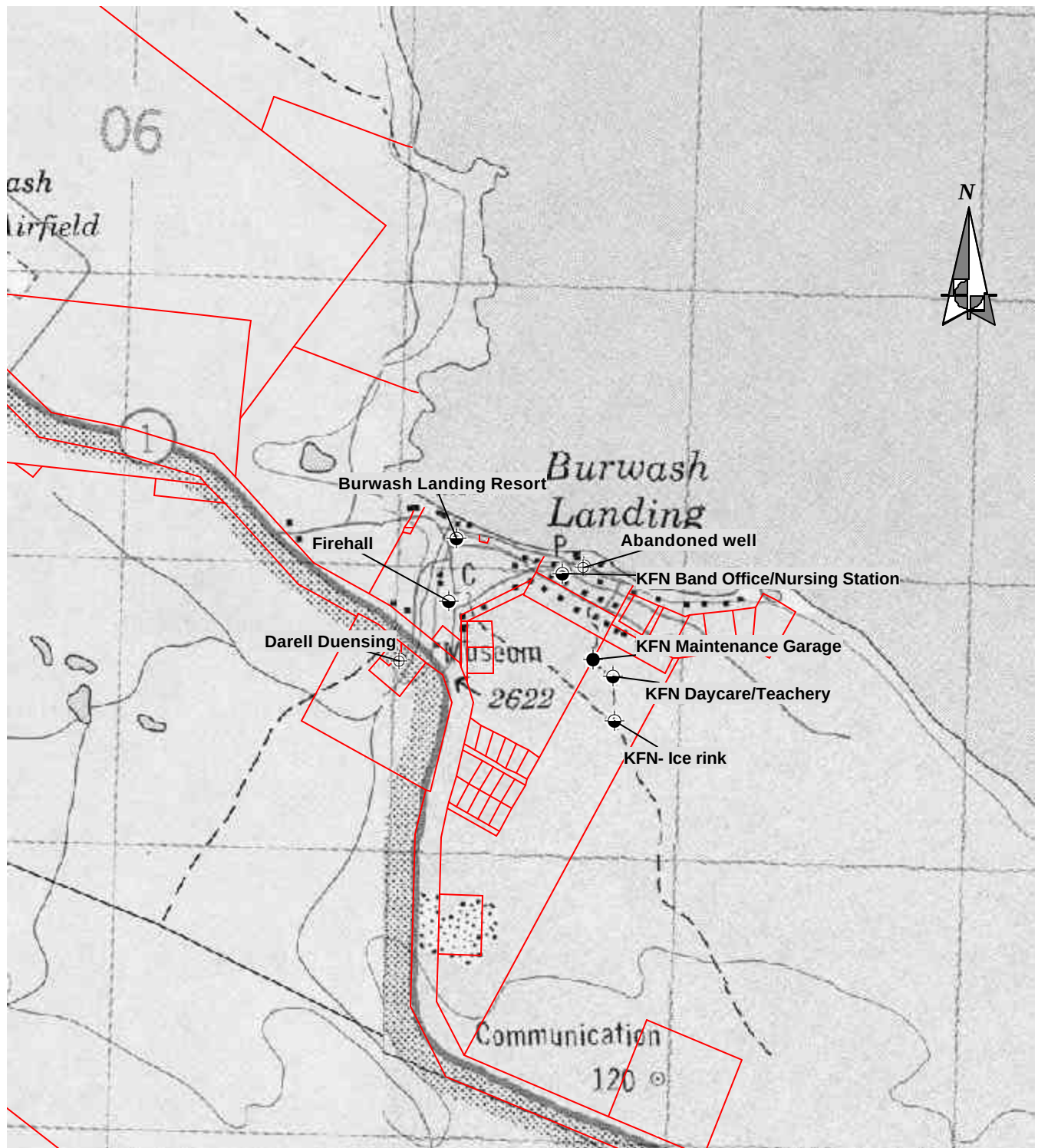
4.2.2 Burwash Landing Climate

Climate normal data for the Burwash Landing Airport, based on the period 1996 to 2001, are summarized in Table 4.2-1.

Table 4.2-1 Climate Normals for Burwash Landing, 1996-2001

Month	Mean Temperatures – Burwash Landing (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-14.84	-26.28	-20.56	7.54
February	-6.66	-21.62	-14.16	5.32
March	-2.28	-18.90	-10.60	5.16
April	5.74	-7.30	-0.76	5.66
May	11.72	-1.88	4.94	23.54
June	18.56	4.78	11.70	53.46
July	19.46	7.02	13.28	62.46
August	17.54	4.46	11.02	42.72
September	9.10	-0.70	4.22	16.32
October	1.28	-9.14	-3.92	24.62
November	-6.84	-17.62	-12.28	9.46
December	-12.70	-24.40	-18.52	13.52
Year	3.34	-9.30	-2.97	269.78

Source: Environment Canada 2002.



Scale: 1:20,000

LEGEND:

Identified Water Well Locations
(number of wells)

-  Commercial/Institutional (5)
-  Domestic (2)
-  Municipal/Communal (1)

Source of Drawing:
Energy, Mines and Resources Canada,
1983 National Topographic Series 115 G/6.7
Reviewed By: MG
Drawn By: GC
Revised: October, 2003
Project Number: 22-680
File Name: 22680_BRWS_fig1_Final.WOR
Revision: 0

**Burwash Landing
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.2-1**

4.2.3 Burwash Landing Topography and Hydrology

Burwash Landing occupies a portion the Burwash Flats on the Yukon Plateau. The community is southeast of the confluence of the Kluane River with Kluane Lake at an elevation of approximately 800 m (2,620 feet) amsl. A creek flows through the community. Mountains of the Kluane Range (to the west) rise to elevations above 1,980 m amsl. Most surface runoff originating near the adjacent mountains flows toward Kluane Lake. The nearest surface water bodies to Burwash Landing are Kluane Lake (adjacent to the community), the Kluane River (approximately 8 km to the northwest) and the Duke River (approximately 8 km north).

4.2.4 Burwash Landing Geology

The most recently published surficial geology map of the Beaver Creek area is by Rampton (1978). The results of terrain analysis completed as part of this project are shown on Figure 4.2-2.

Near-surface soil near the community is inferred to consist mainly of gravelly alluvial fan deposits that overlie rolling deposits of till. The till is exposed northwest and southeast of town, where it displays elongated drumlin-like features. Gravelly beach deposits (too small to be shown on Figure 4.2-2) are likely developed along the lake shore and these deposits likely host some of the town's dug wells. Other dug wells are likely completed in the gravelly alluvial sediments.

The nearest bedrock exposures are on mountain slopes approximately 4 km southwest of the community. Bedrock exposed along the toe of the mountains is described as basalt and andesite of the Nicolai Formation (Gordey and Makepeace 2000). Depth to bedrock under the community is not identified. However, based on observations elsewhere in the Shakhwak Trench, depth to bedrock beneath the community may be several hundreds of meters. The borehole for the Quill Creek/Wellgreen Mine well (located 25 km northwest of the community) did not encounter bedrock and is reported to be approximately 365 m deep (Hydrogeological Consultants Ltd. 1978).



LEGEND:

Primary Surficial Material

- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- M - Morainal (till)



Gravel Pit

Note: See Figure 2.2-1 for the terrain interpretation legend

Source of Drawing:
Energy Mines and Resources Canada,
1983. National Topographic Series 115 G/6,7

Reviewed By: FKP

Drawn By: NS/FKP

Revised: June 2003

Project Number: 22-680

File Name: 22680_BURL_surfgeo.WOR

Revision: 0

Burwash Landing Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Lee

Figure No.

4.2-2

4.2.5 Burwash Landing Hydrogeology

The Shakwak Valley beneath and near Burwash Landing contains hundreds of feet of unconsolidated alluvium and glacial till in its deepest parts. There is a potential for multiple aquifers to be developed within these sediments. The mountains of the Kluane Range likely provide much of the groundwater recharge to aquifers beneath Burwash Landing.

Locations of identified water wells in Burwash Landing are shown on Figure 4.2-2. Most identified wells are shallow. These wells are likely completed in the shallow alluvial and Kluane Lake beach deposits. However, completion depths for these wells are not identified in the reviewed documents. Based on local topography, and assuming that the direction of unconfined groundwater flow is influenced by surface topography, shallow groundwater beneath Burwash Landing is inferred to flow north to northeast (toward Kluane Lake).

Deeper groundwater flow is difficult to characterize using the reviewed information. Intera (1975) reported that in 1968, a 76 m deep well was installed to supply water to the community wash house. The depth to static water in the well is reported to have been approximately 6.1 m. Prior to 1965, a 48 m deep well was installed at a lodge in the community. In 1965, this well was reported to be artesian and to flow at a rate of approximately 1.3 L/s. Historic groundwater usage information is not reported for either private wells or the KFN wells in Burwash Landing.

4.2.6 Burwash Landing Community Visit

Gartner Lee visited Burwash Landing on December 10, 2003. During this visit, Gartner Lee personnel visited the following:

- Mr. Dennis Dickson of KFN. Mr. Dickson provided information regarding four KFN community wells. Minimal information was available from KFN records. Mr. Dickson also provided access to the KFN wells and identified locations of two KFN wells in Destruction Bay and provided contact names for access to these wells. Groundwater field measurements were made at the Teacherage well, the KFN Office well and the Maintenance Garage well. The ice rink well was not in operation and was not available for groundwater observation.
- Mr. John Obermeyer. Mr. Obermeyer provided access to the Firehall well.
- The Burwash Landing Lodge. The lodge is equipped with two water wells. One supplies the main restaurant and lounge and the other supplies cabins. At the time of the visit, the latter well had been taken off-line for the winter and was not available for field measurements.
- Mr. Darrell Duensing. Mr. Duensing is the owner of a private well that is located west of the Alaska Highway. Mr. Duensing reported that he has had no problems with the operation his well.

The results of groundwater field measurements by Gartner Lee on December 10, 2002 are summarized in Table 4.2-2.

Table 4.2-2 Burwash Landing Groundwater Field Parameters Measured on December 10, 2002

Location	Temp. (°C)	pH (pH units)	Electrical Conductivity (µS/cm)	Field Hardness	Comments
Burwash Landing Resort	10.1 ^a	7.08	584	Very hard	Tap in kitchen, large holding tank
KFN Band Office and Nursing Station	5.0	8.26	408	N/A	
KFN Maintenance Garage	1.3	8.31	402	Hard	
KFN Daycare and Teacherage	1.7	8.26	248	Hard	
Darrell Duensing	2.6	8.29	218	Hard	Across from service station
Firehall	3.2	8.53	345	Hard	Hydrogen sulfide odor

^a Sample from tap in kitchen, holding tank likely not purged due to time/owner constraints.

4.2.7 Burwash Landing Water Supply

Residents of Burwash Landing obtain potable water from private wells and four KFN community wells. Drinking water is distributed using a truck that is filled at the maintenance garage well (located on KFN land). All identified wells are likely completed within a shallow unconfined aquifer that is developed near the shore of Kluane Lake. Completion depths for these wells are not identified in the reviewed materials.

4.2.8 Quality of Groundwater in Burwash Landing

Selected historical groundwater quality information that is relevant to the operation of GSHP systems is summarized in Table 4.2-3.

Table 4.2-3 Selected Characteristics of Burwash Landing Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Yukon Church Residence ^a	-	-	144	0.06	0.08	UMA Engineering Ltd. (UMA), 1988
Elder's home ^a	-	-	<1	0.13	0.03	UMA, 1988
Wash house well ^a	-	-	199	0.07	0.07	UMA, 1988
Trailer north of Elder's home ^a	-	-	156	0.08	0.06	UMA, 1988
Health Clinic / Band Office	8.47	128	205	0.04	0.075	Gartner Lee, 2002a
Teacherage and Daycare	8.52	145	230	0.11	0.032	Gartner Lee, 2002a
Maintenance Garage	8.45	109	164	<0.03	0.069	Gartner Lee, 2002a

A: location of well is not identified in reviewed documents.

4.2.9 Burwash Landing GSHP Potential

GSHP Type	Potential	Comments
GWHP	Moderate to High	- Development of groundwater seems to be relatively successful, however winter groundwater temperatures are suspected to be cold due to proximity to land surface and/or surface water. - Water quality for GWHP appears to be relatively good. - Potential for development of groundwater from deeper aquifers that may yield higher temperature water.
GCHP	Moderate to Good	Good potential for thermal transfer due to groundwater flow through saturated alluvial gravel deposits, however till maybe encountered at depth.

Based on information presented in the 1975 Intera report, there is potential for GSHP development of deeper aquifers (at depths of greater than 80 m) beneath the community. Such aquifers should yield groundwater that is not influenced by surface temperatures, and that may be suitable for use in GSHP systems. Exploration drilling is required to confirm this potential.

4.3 Carcross

4.3.1 Carcross Community Description

Carcross is located near the north end of Lake Bennett near the Yukon-British Columbia border approximately 72 km south of Whitehorse. Carcross is immediately north of "The Narrows" (Nares River) between Bennett Lake (to the west) and Tagish Lake (to the east). A map showing Carcross and nearby topography (along with identified well locations) is shown in Figure 4.3-1. A community profile of Carcross appears in Appendix A.

Carcross was originally developed as a hunting and fishing camp. Later, it became a stopover and supply centre during the Klondike Gold Rush. In 1901, when the White Pass and Yukon Railway station was constructed, Carcross became a major transportation centre. Currently, Carcross is a Klondike Highway service and tourist centre. Carcross has a population of 394 (Yukon Bureau of Statistics 2003).

Members of the Carcross/Tagish First Nation (CTFN) occupy several residences south of The Narrows. Electricity for Carcross is supplied by Yukon Energy Corporation (YEC) from Whitehorse.

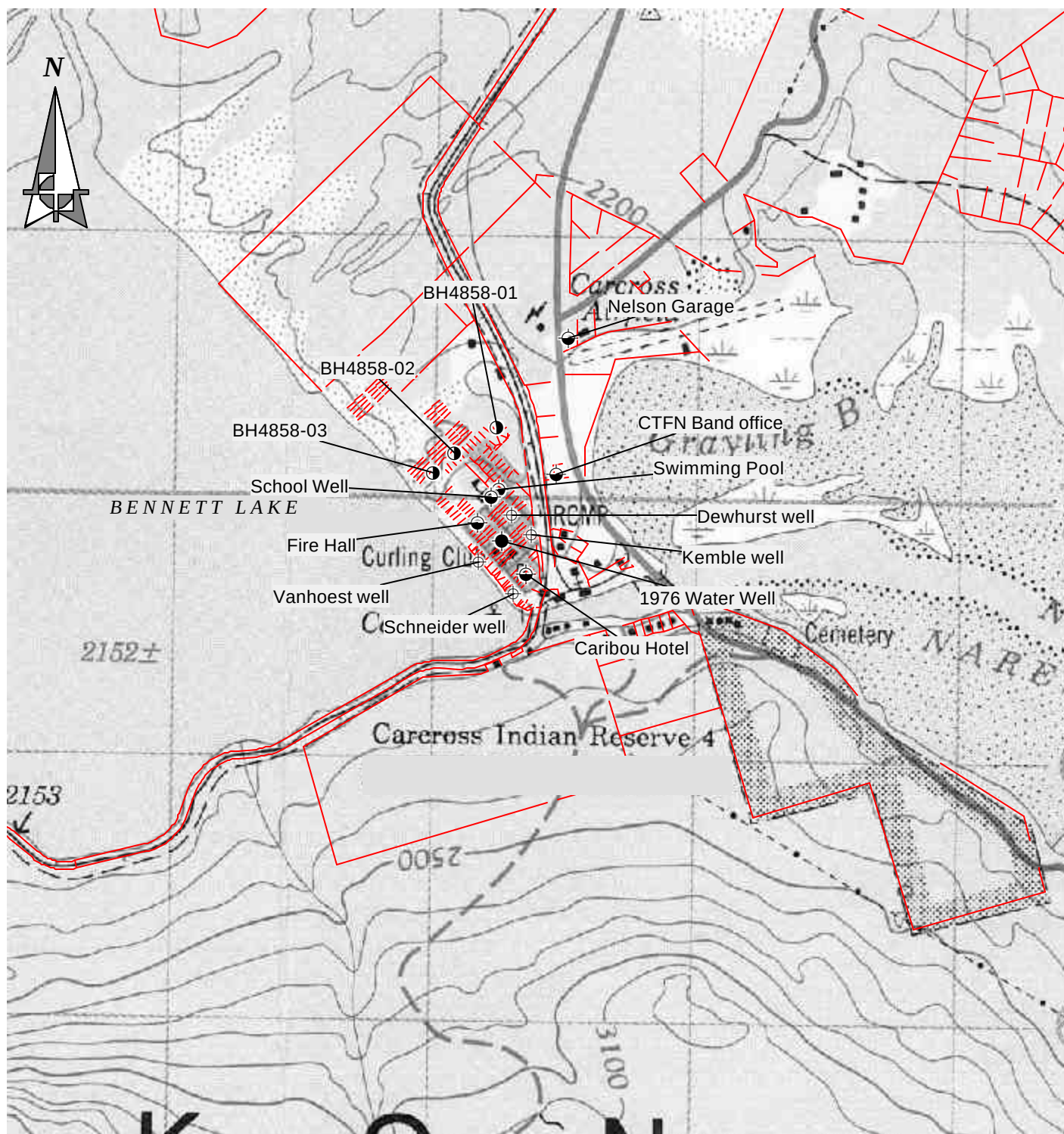
4.3.2 Carcross Climate

Climate normal data for Carcross, based on the period of 1996 to 2001, are summarized in Table 4.3-1.

Table 4.3-1 Climate Normals for Carcross, 1996 – 2001

Month	Mean Temperatures – Carcross (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-14.12	-22.78	-16.94	59
February	-5.72	-18.14	-11.94	14.28
March	0.38	-14.44	-7.5	7.8
April	7.12	-6.58	0.98	6.9
May	12.48	-2.02	5.58	22.22
June	19.36	3.9	11.52	33
July	19.68	6	12.94	36.9
August	19.36	4.66	12.16	24.2
September	12.45	2.35	7	38.95
October	4.66	-3.96	0.94	21.48
November	-2.86	-9.76	-6.22	17.98
December	-6.6	-16.06	-11.22	25.72
Year	5.52	-6.40	-0.23	308.43

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND: Identified Water Well Locations

- Commercial/Institutional
- ⊕ Domestic
- Geotechnical
- Municipal/Communal

Source of Drawing:
Energy, Mines and Resources Canada,
1986, National Topographic Series 105D/2
Reviewed By: FKP
Drawn By: GC
Revised: June 25, 2003
Project Number: 22-680
File Name: 22680 CarX fig1 Final.WOR
Revision: 0

**Carcross
Known Well Locations**

Yukon Groundwater and Ground Heat
Potential Inventory



Figure No. **4.3-1**

4.3.3 Carcross Topography and Hydrology

Bennett Lake, Nares Lake and the Nares River are part of the headwaters of the Yukon River. Bennett Lake drains east, through the Narrows, into Nares Lake. Water levels in these water bodies fluctuate seasonally, with annual low-water levels typically occurring in May at an elevation of approximately 654 m amsl. Seasonal high-water levels typically occur in August or September, at an elevation of approximately 650 m amsl. The highest reported flood elevation of the waterway near Carcross between 1947 and 1980 was 657 m amsl.

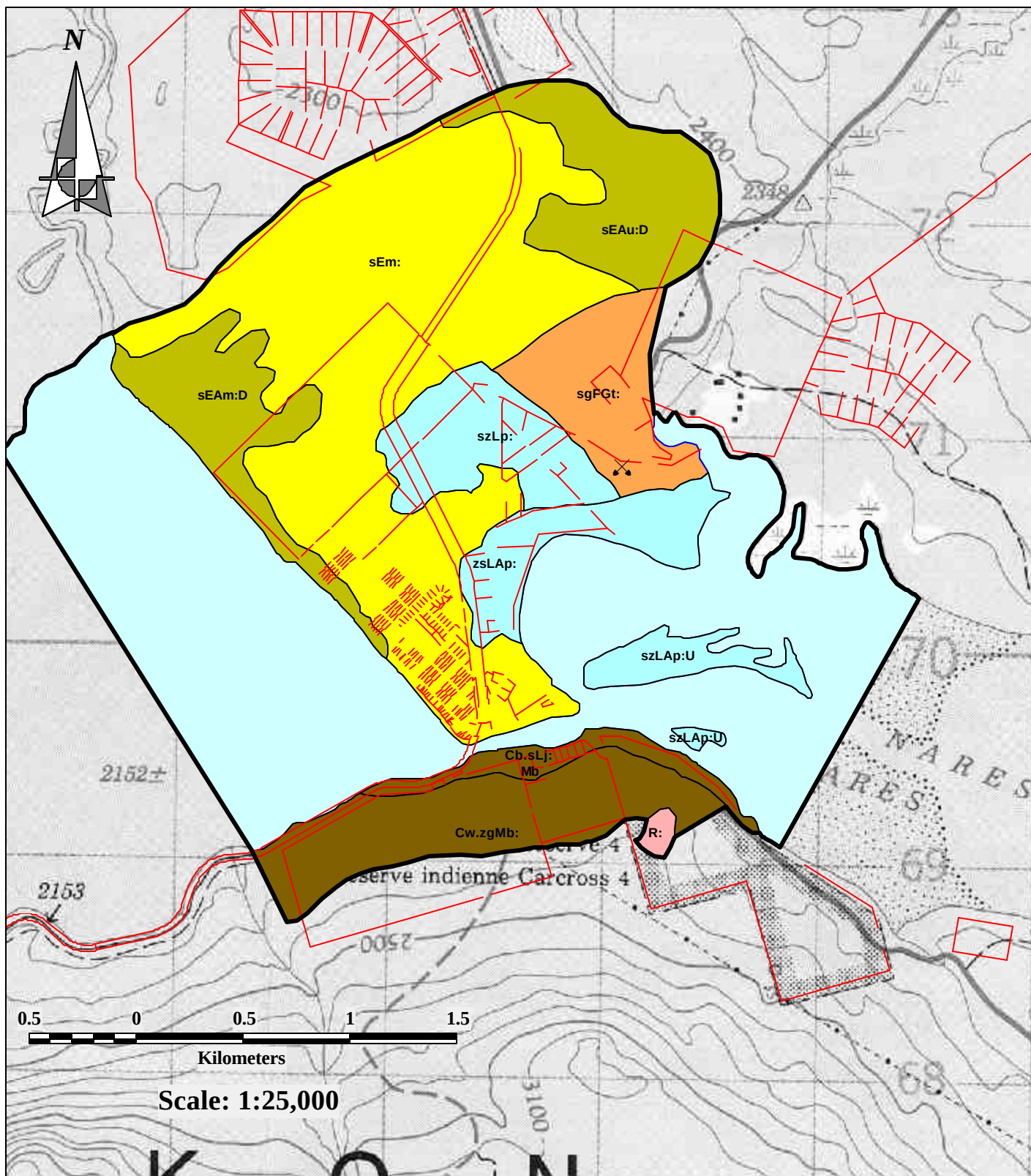
4.3.4 Carcross Geology

Terrain conditions near Carcross are shown on Figure 4.3-2. The community is located on a rolling sandy plain between Bennett Lake and Nares Lake. Across the Nares River, the terrain rises up the flanks of Montana Mountain. The community lies on eolian sand (e.g., wind-blown sand dunes) derived from Bennett Lake. Surficial soil consists mainly of well-sorted sand. The dune field is active along the beach north of the community. The town airstrip lies on the lacustrine plain of Nares Lake northeast of the community core. Fine grained lacustrine sediments extend beneath the near-surface eolian sands. Glaciofluvial sand and gravel deposits are exposed northeast of the community along the Tagish Road.

The nearest bedrock is exposed along the Klondike Highway south of the Nares River bridge. Bedrock mapping indicates that the town is likely underlain by quartz monzonite and biotite quartz-rich granite. East of town, bedrock is reported to be andesite and basalt (oceanic volcanic rock) of the Cache Creek Group (Gordey and Makepeace 2000). The depth to bedrock beneath the community ranges from 71 m (at the maintenance garage well, Intera 1976) to greater than 100 m.

4.3.5 Carcross Hydrogeology

Locations of identified water wells in Carcross are shown on Figure 4.3-1. Most identified wells and many private wells that were used prior to 1976 are reported to be shallow dug wells that were completed in sand between depths of 4 m and 6 m. These wells are developed in a shallow, unconfined aquifer. Assuming that the direction of unconfined groundwater flow beneath Carcross is influenced by surface topography, shallow groundwater is likely to flow toward the Narrows, Bennett Lake and Nares Lake. Shallow aquifers near Bennett Lake and Nares Lake and the Nares River are likely to be hydraulically connected to these surface water bodies and conditions within the aquifers are likely to vary seasonally. Deep confined aquifers are also present in the unconsolidated sediments beneath Carcross.



LEGEND:

Primary Surficial Material

- C - Colluvium
- E - Eolian
- EA - Eolian, active
- FG - Glaciofluvial
- L - Lacustrine
- R - Bedrock

Extent of terrain mapping

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Basemap:
Energy, Mines and Resources Canada,
1986, National Topographic Series 105D/2
Reviewed By: FKP
Drawn By: NS/FKP
Revised: June 2003
Project Number: 22-680
File Name: 22680 CarX_surfgeo.WOR
Revision: 0

Carcross Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Figure No.

4.3-2

Prior to 1976, community drinking water for Carcross was obtained from a 82.2 m deep well that was located in the firehall. The well is likely to have been completed within a confined aquifer. The results of pumping tests using the community well that were undertaken prior to 1976 indicated that when tested, the well could not be pumped at rates exceeding approximately 1.9 L/s.

In 1976, a new community well was installed near the firehall. The new well is screened in gravel within a confined aquifer between depths of 102.7 m and 105.8 m. "Blue clay" and "till" were encountered by the well's borehole between depths of 24.6 m and 65.8 m. Assuming that such soil is laterally continuous, it is likely to act hydraulically as a confining layer.

The results of pumping tests using the 1976 (new) community well were interpreted by Hydrogeological Consultants Limited to indicate that the effective transmissivity of the community water supply aquifer is approximately $3.45 \times 10^{-5} \text{ m}^2/\text{sec}$ and that its long-term safe yield is 5.3 L/sec. During the 1976 tests, the temperature of groundwater in the well was 7 degrees Celsius.

In 1988, EBA Engineering Consultants Ltd. (EBA) undertook single-well response tests using piezometers that were completed within a sand aquifer located approximately 700 m northwest of The Narrows. EBA estimated that the hydraulic conductivity of the tested shallow aquifer ranged between $1.3 \times 10^{-6} \text{ m/sec}$ to $3.3 \times 10^{-7} \text{ m/sec}$.

Additional deep wells within and near Carcross that are identified in the reviewed documents are as follows:

- In 1975, wells at the Carcross School and the "new" Yukon Housing Corp. residence were completed between depths of approximately 54.8 m and 105.5 m. The school well was abandoned in 1982 due to elevated concentrations of arsenic in the groundwater.
- The Government of Yukon (YTG) highway maintenance garage well (installed before 1975) was completed between depths of 72.1 m and 73.9 m in broken rock beneath 35 m of silt, silty sand, clay and silty clay. When installed, the depth to static water in this well was 3.7 m. According to reviewed documents, the long-term yield of the well was 7.6 L/sec.
- A well at the Caribou Hotel is completed a "lower" sand aquifer. Concentrations of arsenic in groundwater from this aquifer are reported to be elevated. The long-term yield of the Caribou Hotel well is reported to be 2.2 L/sec (Stanley Associates 1988).
- A well at the Nelson Garage and, possibly, the community firehall well, are completed within a "deeper" sand and gravel aquifer (Stanley Associates 1988). Concentrations of arsenic in groundwater from this aquifer are reported to be suitable for drinking. However, between 1984 and 1987, a system was installed to treat community water to reduce its concentration of arsenic.

In 1979, an attempt to install a private well south of The Narrows failed when refusal was reached at a depth of approximately 20 m. Associated Engineering Services Ltd. (1980) reported poor potential for

developing water supply wells on or near CTFN lands south of The Narrows (due to presence of shallow bedrock).

Stanley Associates (1984) identified five aquifers beneath and near Carcross as follows:

- a sand aquifer above a depth of approximately 7 m;
- a sand and gravel aquifer between approximately 20 m and 24 m;
- a sand aquifer between 38 m and 42 m;
- a sand and gravel aquifer between 61 m and 67 m; and
- a sand and gravel aquifer from 97 m and 104 m.

Details of groundwater flow characteristics within these aquifers are not identified in the reviewed materials. The presence of a water-treatment system for the community groundwater to reduce concentrations of metals in the water suggests that elevated concentrations metals and total dissolved solids are present.

4.3.6 Carcross Community Visit

Gartner Lee visited Carcross on January 9, 2003. During this visit, Mr. Gavin Cook of Gartner Lee met with the following:

- Mr. Wayne Moulton of CTFN. Mr. Moulton identified that untreated groundwater in the community swimming pool well and the school wells contains elevated concentrations of arsenic.

At the time of the visit, the swimming pool well was not operating and water from the school well was used only for toilets. Groundwater from these wells was not available for monitoring during the visit.

The Caribou Hotel is equipped with a private well. However, at the time of the visit, the hotel was closed for the season and groundwater in the well was not available for monitoring.

Gartner Lee did not measure groundwater field variables in Carcross during the community visit due to lack of availability of monitoring locations.

4.3.7 Carcross Water Supply

Most residents of Carcross obtain water from Bennett Lake. Some obtain water from private wells. Municipal water is treated and chlorinated before distribution. Most members of the CTFN community

(located south of The Narrows) obtain water from a delivery truck that is filled at the Carcross community (firehall) well.

4.3.8 Quality of Groundwater in Carcross

Groundwater quality information of potential significance to the operation of GSHP systems is summarized in Table 4.3-2. Locations of identified wells within Carcross are shown on Figure 4.3-1.

Table 4.3-2 Selected Characteristics of Carcross Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)L	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Firehall Well (April 1976)	6.9 - 8.0	128 - 188	100 - 210	0.21 - 1.33	0.04 - 0.26	Associated Engineering (1980)
Firehall Well (Sept 1976)	8.18	172	180	0.18	-	Hydrogeological Consultants (1976)
Firehall Well (October 1976)	8.12	170	177	0.16	-	Hydrogeological Consultants (1976)
Firehall Well (1987)	8.25	168	160	<0.10	0.07	Stanley Associates (1988)
Schneider Well (1987)	7.24	206	130	<0.10	0.47	Stanley Associates (1988)
Kemble Well (1987)	7.28	174	89	0.16	0.28	Stanley Associates (1988)
Van Zoest Well (location not identified)	7.08	260	76	<0.1	0.05	Stanley Associates (1988)
Carcross Administration Building (Sept. 2001)	6.64	27.8	29	<0.03	<0.002	Gartner Lee 2002
George Dewhurst Well	7.4	-	-	0.56	-	Intera (1975)
Dump Piezometers (1992 - 1993)	7.70 - 8.16	223 - 436	235 - 455	<0.01 - 1.71	0.033 - 1.2	David Nairne & Assoc. (1993)
BH4858-02	7.42	80	88	-	-	EBA (1988)
BH4858-03	7.95	74	74	-	-	EBA (1988)

Identified areas of potential environmental concern, with respect to groundwater quality in and near Carcross include:

- use of conventional in-ground septic disposal systems within the community and use of fuel storage tanks at community buildings and service stations have a potential to impact shallow groundwater systems; and
- There is a potential for presence of elevated concentration of metals, such as arsenic, in groundwater beneath the community.

4.3.9 Carcross GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	• High yield aquifers potentially exist at depth; several underutilized wells are present in the community (e.g. school well, old firehall well and YTG maintenance yard wells). • Opportunity exists for GWHP producing water from the deeper aquifer and rejecting cooled water to the shallow aquifer.
GCHP	Low to Moderate	• Soils become fined grained at depth resulting in lower anticipated thermal conductivity values, drilling should be relatively easy.

Carcross contains several deep wells that are underutilized due to drinking water quality issues (such as elevated concentrations of arsenic). These include the school well and the old firehall well. These two wells may be suitable for use in GSHP systems for the school, with one well used as a production well and the second as an injection well. *It is recommended that the school and firehall wells be inspected and a desktop feasibility assessment be completed for construction of a GWHP system for the Carcross School.*

A second potential GSHP development opportunity may exist with the YTG Highway Maintenance Compound well. This well was reported to flow at over 7 L/s (more than 100 igpm) and could potentially be used to heat the Compound buildings. *It is recommended that the YTG Highway Maintenance Compound well be inspected and a desktop feasibility assessment be completed for construction a GWHP system for this facility.*

4.4 Village of Carmacks

4.4.1 Carmacks Community Description

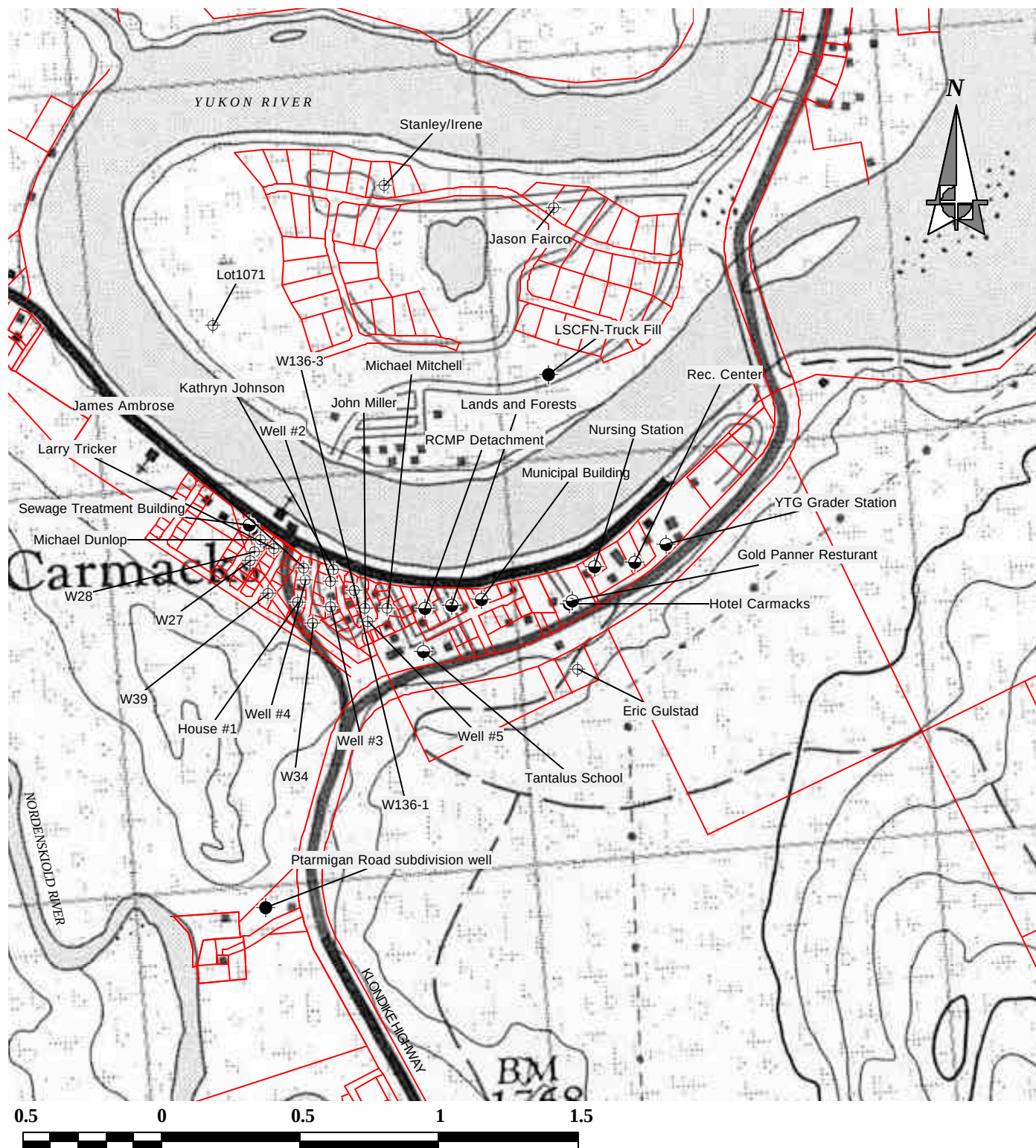
The Village of Carmacks is located approximately 180 km north of Whitehorse along the Klondike Highway at its junction with the Robert Campbell Highway. Carmacks is located immediately south of the Yukon River near the Nordenskiöld River confluence. The community is a highway service centre and is home to the Little Salmon/Carmacks First Nation (LSCFN). A location map that shows Carmacks and nearby topography appears as Figure 4.4–1. Carmacks has a population of 407 (Yukon Bureau of Statistics 2003). A community profile of Carmacks appears in Appendix A. Electricity for Carmacks is supplied by the Yukon Energy Corporation (YEC) Whitehorse-Aishihik-Faro grid using emergency diesel generators.

The Carmacks Industrial Park subdivision is located between the Nordenskiöld River and the Klondike Highway approximately 15 km south of Carmacks. The LSCFN Village is located within a meander of the Yukon River north of and across the Yukon River from Carmacks. Additional LSCFN developments near Carmacks include:

- The Nordenskiöld subdivision, located north of the Nordenskiöld River near its confluence with the Yukon River;
- The Johnsonville subdivision, located south of the Yukon River between Carmacks and the confluence of the Nordenskiöld River with the Yukon River; and
- The Ptarmigan Road subdivision, located between the Klondike Highway and the Nordenskiöld River approximately 0.75 km south of Carmacks.

4.4.2 Carmacks Climate

Climate normal data for Carmacks for the period 1996 to 2002 are summarized in Table 4.4-1.



Scale: 1:15,000

LEGEND:

Identified Water Well Locations
(number of wells)

- ⊗ Commercial/Institutional (10)
- ⊕ Domestic (21)
- Municipal/Communal (2)

Source of Drawing:
Energy, Mines and Resources Canada,
1963, National Topographic Series 115/I
Reviewed By: FKP
Drawn By: GC
Revised: October, 2003
Project Number: 22-680
File Name: 22680 CMK_fig1_Final.WOR
Revision: 0

**Carmacks
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No.

4.4-1

Table 4.4-1 Climate Normals for Carmacks, 1997-2002

Month	Mean Temperatures – Carmacks (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-16.18	-29.88	-23.02	17.1
February	-8.36	-22	-15.28	9.7
March	0.18	-19.38	-9.98	6
April	8.94	-6.92	1.02	8.56
May	15.1	0.14	7.46	28.8
June	22.16	7.08	14.56	44.24
July	22.18	8.58	15.34	48.62
August	21.22	5.76	13.56	50.42
September	13.98	-0.18	6.98	41.76
October	3.85	-7	-2.18	22.74
November	-7.66	-15.54	-11.34	17.9
December	-13.48	-24.3	-19.24	18.16
Year	5.16	-8.64	-1.84	314

Source: Environment Canada 2002.

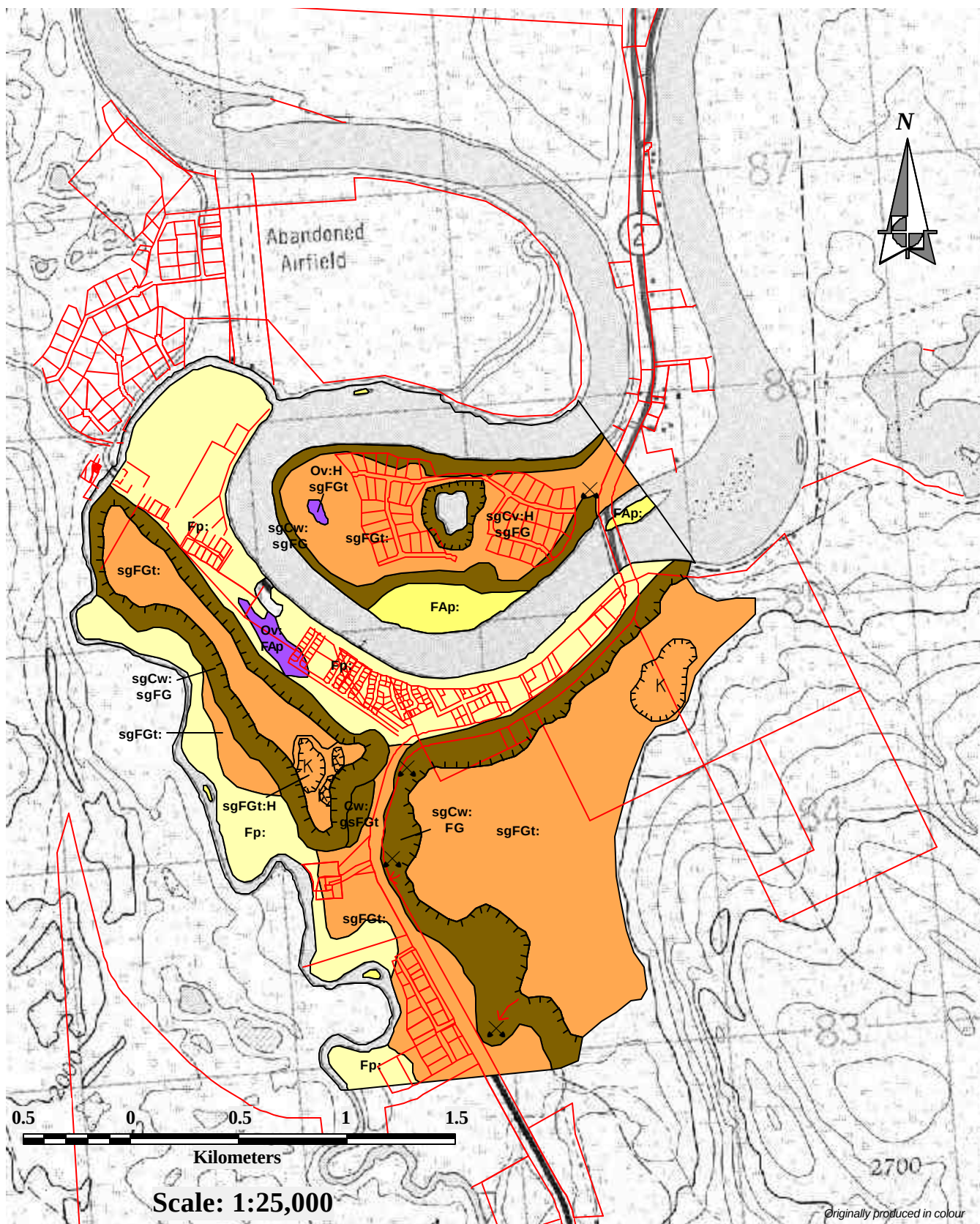
4.4.3 Carmacks Topography and Hydrology

Carmacks is developed on the floor of the Yukon River Valley. In general, storm water runoff that originates within and near the village flows toward nearby rivers. The average elevation of the Yukon River near Carmacks is approximately 519 m amsl. Historically, between April and November, the level of the Yukon River near Carmacks has fluctuated approximately 2.5 m. The highest levels of the Yukon River usually occur in July and August. Annual water levels in the Nordenskiöld River typically fluctuate approximately 0.5 m.

Carmacks is within an area of discontinuously developed permafrost. However, permafrost conditions are not reported to be developed within the village. South of Carmacks, "ground ice" has been observed between depths of 5 m and 8 m.

4.4.4 Carmacks Geology

The results of a terrain interpretation of the Carmacks area are shown on Figure 4.4-2. The village is situated on a low alluvial terrace of the Yukon River and is bounded to the south and west by high sand and gravel glaciofluvial terraces. Soil underlying the community is primarily coarse fluvial sand and gravel. The alluvial deposits likely overlie glaciofluvial sediments which can be heterogeneous, ranging from silt to sand and gravel. Bedrock is exposed immediately east of the Yukon River bridge.



LEGEND: Primary Surficial Material: C - Colluvium F - Fluvial FA - Fluvial, active FG - Glaciofluvial O - Organic

Gravel Pit Kettle Escarpment Landslide/Mass Movement

Extent of terrain mapping

Note: See figure 2.2-1 for terrain interpretation legend

Source of Basemap:
Energy, Mines and Resources Canada,
1963. National Topographic Series 115/I
Reviewed By: FKP
Drawn By: NS/FKP
Revised: January 14, 2003
Project Number: 22-680
File Name: 22680_CMK_surfgeo.WOR
Revision: 1

Carmacks Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Figure No. **4.4-2**

Bedrock underlying the village is primarily bedded chert pebble conglomerate and sandstone of the Tantalus Formation (Gordey and Makepeace 2000). Coal seams occur locally.

4.4.5 Carmacks Hydrogeology

Locations of water wells in Carmacks that are identified in the reviewed documents are shown on Figure 4.4-2. Most identified wells are completed in one or more shallow unconfined sand and gravel aquifers near the Yukon River. The elevation of the water table beneath Carmacks fluctuates seasonally in response to water level fluctuations in the Yukon River. The water table is reported to be, in general, approximately 3 m below ground surface. Typically, the highest annual water table elevations occur in June and July.

The shallow unconfined aquifers beneath Carmacks are extensively developed as sources of potable water. Based on grain size analyses, EBA estimated that the hydraulic conductivity of the shallow sand and gravel aquifers is likely to range between 4×10^{-4} m/sec and 1.0×10^{-6} m/sec. Assuming that the direction of unconfined groundwater flow is influenced by surface topography, the direction of shallow groundwater flow beneath and near Carmacks is inferred to be mainly toward the Yukon River. During high-stage conditions in the Yukon River, there is a potential for the river to act as a groundwater recharge zone and for groundwater beneath Carmacks to flow away from the river. A potential exists for deep confined aquifers to be present within the thick unconsolidated sediments beneath Carmacks. However, to our knowledge, this has not been explored to date.

Unconfined groundwater east of the Nordenskiöld River near the Ptarmigan Road and Carmacks Industrial subdivisions is inferred to flow mainly northeast (from the Nordenskiöld River to the Yukon River) (R. Martin, pers. comm. 2003).

4.4.6 Carmacks Community Visit

Gartner Lee visited Carmacks on December 10, 2002 and January 8, 2003. During the visit, the following individuals and locations were visited:

- Mr. Bob Jackman of the Village of Carmacks. Mr. Jackman provided Gartner Lee with groundwater related reports.
- Gartner Lee attempted to monitor groundwater conditions at locations for which borehole logs were available. Orange staining of fixtures and sulphurous odors were identified at most monitoring locations. Residents of several Yukon Housing residences currently treat their groundwater using ultraviolet light (UV) systems.

Yukon Groundwater and Ground Source Heat Potential Inventory

- The Government of Yukon (YTG) Grader Station. The well is reported to be approximately 50 m deep. Groundwater in the well is reported to be of poor (aesthetic) quality. Heavy orange staining of fixtures and a strong sulfurous odor were identified during monitoring. The water is reported to not be used for drinking.
- The Carmacks Nursing Station. The station is equipped with a water treatment system.
- The Hotel Carmacks/Gold Panner Inn well. Low-flow problems were identified and orange staining of fixtures was reported.
- Mr. Terry Billy, Capital Projects Director for LSCFN. Mr. Billy provided access to three private LSCFN wells. Orange staining of fixtures and sulphurous odors are associated with groundwater from each of the wells.
- LSCFN community (truck fill) well. The well water is chlorinated prior to being distributed. No concerns with respect to water quality were identified.
- Ptarmigan Road subdivision community well.

The results of groundwater field measurements by Gartner Lee on December 10, 2002 are summarized in Table 4.4-2.

Table 4.4-2 Carmacks Groundwater Field Parameters Measured on December 10, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µmho/cm)	Hardness	Comments
Hotel Carmacks	4.5	7.6	512	Very hard	Well is in basement; orange staining, rust odor, low-flow problems
Gold Panner Inn	3.0	7.6	456	Very hard	Well is in basement; orange staining, well services adjacent building also
Carmacks Municipal Building	3.7	7.5	425	Very hard	Orange staining, no odor
Lands and Forests	4.8	7.6	412	Hard	Well in Basement; orange staining, no odor
YTG Grader Station	3.9	7.6	485	Very hard	Sulfur odor, orange staining, not used for drinking
Recreation Center	4.8	7.4	518	Very hard	Clear, no odor, no concerns reported
Nursing Station	6.2	7.6	605	Soft	Well is in a heated shed; treated water was monitored, orange staining noted

Yukon Groundwater and Ground Source Heat Potential Inventory

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µmho/cm)	Hardness	Comments
RCMP Detachment	5.5	7.4	385	Very hard	Could not locate well; orange staining, no odor, well apparently at adjacent house
Sewage Treatment Plant	4.5	7.5	384	Hard	Well in Basement; filter stained dark orange, sulfur odor
Tantalus School	4.3	7.5	403	Hard	Orange staining, no odor
Mikeel Mitchell well	4.5	7.4	425	Hard	Well in Basement; orange staining, no odor

4.4.7 Carmacks Water Supply

Most Carmacks residents and users obtain water from private wells that are completed between depths of approximately 6.4 m and 18.3 m. Locations of identified wells in Carmacks are shown on Figure 4.4-1.

In 2001, EBA Engineering Consultants (EBA) reviewed borehole logs and well installation details for approximately 30 private wells within and near Carmacks. EBA reported that well completion depths ranged between 11 m and 55 m and averaged approximately 16 m. EBA also noted that when monitored, the static elevation of groundwater in most wells corresponded, approximately, with the elevation of water in the Yukon River. Information in G.J. Bull and Associates Inc.'s 2002 report identifies the locations of most private wells in Carmacks. EBA reported that completion depths for five Ptarmigan Road subdivision private wells range between approximately 9.2 m and 12.2 m.

The LSCFN Village "Water Shed" well is north of Carmacks within the Village Subdivision. In 2002, chlorinated water from this well was supplied to the Village Heritage Hall, the Village Health & Social Building/Daycare building and the Village's old (vacant in 2002) Daycare building. Water from the well was also provided to four Village residences, the Village Visitor Reception Centre, the Village public campground and other locations. The well is reported to be completed above a depth of approximately 15 m.

The LSCFN Village Wash House well is completed between depths of 14.3 m and 14.9 m and 16.8 m and 19.8 m (two screened intervals) in a sand and gravel aquifer. The well is reported to have yielded up to 38 L/min of water. The reported depth to static water in the well prior to 1975 is 6.1 m.

The Ptarmigan Road Subdivision (community) well is completed above a depth of 10.5 m. In 2002, residents of approximately 40 houses used water from this well for drinking. In 2002, six Ptarmigan Road Subdivision residences were equipped with private wells.

Water for the LSCFN Administration Building and the Carmacks Campus of the Yukon College (both located in the First Nations Village) is provided by one well that is located near the LSCFN Administration Building. In 2002, 25 to 65 persons per day used water from the well. The LSCFN Administration Building well is completed above a depth of approximately 15 m. Water from the well is pumped to a pressure tank prior to its being distributed without treatment using a piped delivery system.

In 2002, most LSCFN Village buildings were equipped with private wells. In 2002, approximately 72 private wells provided water to over 500 LSCFN members living in 96 residences. Most private LSCFN wells are completed at depths exceeding 50 m and the aesthetic quality of groundwater yielded by the wells is reported to be variable. Because of groundwater aesthetics issues, many LSCFN members prefer to use groundwater from the Ptarmigan Road subdivision community well for drinking.

In approximately 1975, six private residential wells were installed for Yukon Housing Corporation above a depth of approximately 12.2 m. The wells were completed in sand and gravel in one or more inferred unconfined aquifers. Each well was estimated to be capable of yielding water at a rate of between 1.3 L/s and 2.3 L/s.

4.4.8 Quality of Groundwater in Carmacks

Selected groundwater quality information relevant to the operation of GSHP systems is summarized in Table 4.4–3.

Table 4.4-3 Selected Characteristics of Carmacks Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)L	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
LSCFN Village Water Shed (November 2001)	8.33	245	265	0.49	0.147	Gartner Lee (2002)
LSCFN Administration Building (November 2001)	8.36	159	204	0.17	0.091	Gartner Lee (2002)
Viola Mullet Well (May 2000)	-	113	105	-	-	EBA (2001)
Johnnie Sam Well (May 2000)	-	165	158	-	-	EBA (2001)
David Thom Well (May 2000)	-	192	188	-	-	EBA (2001)
Vera Charlie Well (May 2000)	-	168	172	-	-	EBA (2001)
Gloria Cashun Well (May 2000)	-	199	199	-	-	EBA (2001)

Due to the shallow, unconfined and permeable nature of the Carmacks aquifers and overlying soil beneath Carmacks, these aquifers are vulnerable to surface contamination.

4.4.9 Carmacks Groundwater Temperatures

Gartner Lee measured groundwater temperatures in Carmacks during the December 10, 2002 community visit. The results of the measurements appear in Table 4.4-2.

G.J. Bull & Associates (2002) collected water quality samples from several wells between June and November 2001. Groundwater temperature was measured as part of this work. The results of the measurements are summarized in Table 4.4-4.

Table 4.4-4 Groundwater Temperatures in Carmacks

Number of Wells Sampled	Sample Date (2001)	Groundwater Temperature Range (Degrees C)		
		Minimum	Maximum	Average
8	June 20	5	12	8.4
7	July 4	5	10	7.1
14	August 1	4	9	6.2
9	August 8	5	12	7.9
13	September 5	5	13	5.7
12	September 12	5	8	6.6
14	October	5	13	7.8
6	October 9	5	10	7.2
12	October 17	4	10	5.6
9	October 24	5	11	7.3
15	November 5	5	12	7.8
14	November 7	5	8	6.3

4.4.10 Carcross GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	• High yield aquifers exist near surface. • Groundwater temperatures appear to be relatively stable and somewhat warm. • Poor water quality may require special consideration during design and operation of GWHP systems. • Groundwater disposal should be relatively easy • Warmer groundwater may be found in unconsolidated sediments with depth.
GCHP	Moderate to good	• Coarse grained saturated soils provide relatively good thermal conductivity. • Good groundwater flow under community is anticipated

Development of groundwater appears to be relatively easy in Carmacks. Furthermore, groundwater temperatures do not appear to become too cold in winter. Therefore, there appears to be a good development potential for GWHP systems in this community. *It is recommended that a feasibility assessment of a GSHP heating system for the proposed new Carmacks School be completed.* GWHP systems should also be considered for use in heating other facilities in the community.

4.5 City of Dawson

4.5.1 Dawson City Community Description

Dawson City is near the east shore of the Yukon River at the confluence of Klondike River. The city is approximately 536 km northwest of Whitehorse. Road access is provided by the Klondike Highway from the east or the Top of the World Highway from the west. A location map that shows Dawson City and surrounding topography is shown in Figure 4.5–1. A community profile of the city appears in Appendix A.

Dawson City was established in 1896 when gold was discovered in the Klondike Valley. By the summer of 1898, Dawson City had a population of 40,000. City infrastructure developed quickly to accommodate the rapid population growth. By 1902, after the gold rush, Dawson City's population had declined to 5,000. Currently the population of Dawson City is 1,765 (Yukon Bureau of Statistics 2003) and it is the Yukon's second largest community.

The Dawson City area is home to the Tr'ondek Hwech'in First Nation (THFN). Electricity is supplied by Yukon Energy Corporation (YEC) using a diesel generation plant near the city's water supply main pumphouse and reservoirs. A Mayo-to-Dawson electricity transmission line is scheduled to provide electricity from Mayo Hydroelectric project.

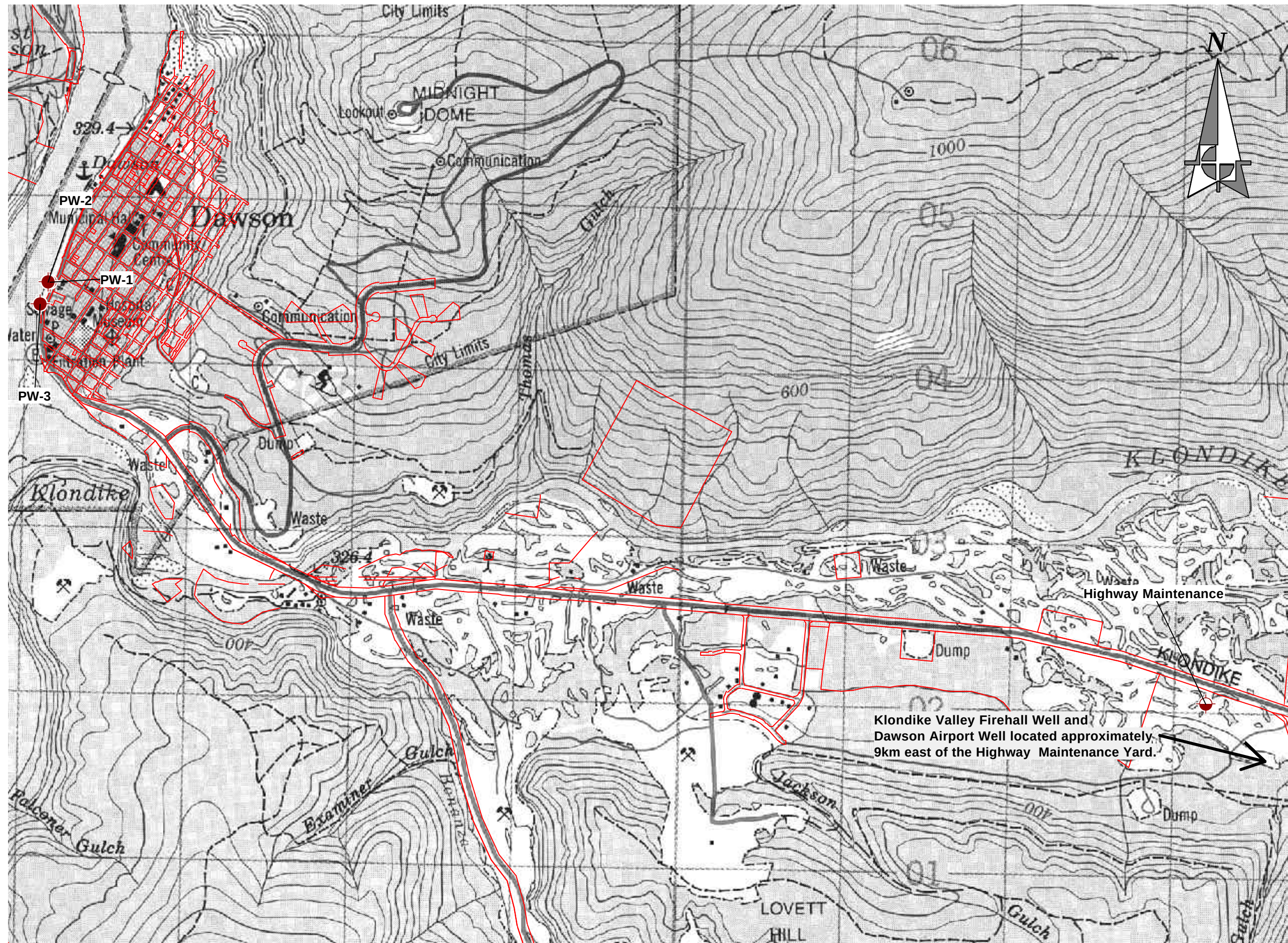
4.5.2 Dawson City Climate

Climate normal data for the Dawson City Airport for the period of 1996 to 2001 are summarized in Table 4.5-1.

Table 4.5-1 Climate Normals for Dawson City, 1996-2001

Month	Mean Temperatures – Dawson Airport (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-22.28	-31.16	-26.72	17.86
February	-13.04	-23.38	-18.24	9.54
March	-3.1	-19.88	-11.5	5.24
April	7.74	-6.9	0.42	6.36
May	14.7	0.58	7.66	29.48
June	22.08	7.12	14.62	47.64
July	23.02	8.82	15.92	59.76
August	19.62	5.9	12.78	38.16
September	12.82	0.4	6.64	29.06
October	-0.72	-9.8	-5.28	31.7
November	-10.92	-18.46	-14.72	14.94
December	-18.24	-26.9	-22.58	25.4
Year	2.64	-9.47	-3.42	315.14

Source: Environment Canada 2002.



LEGEND:

Known Water Well Locations
(number of wells)

- Commercial/Institutional (3)
- Municipal/Communal (3)

0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

Source of Basemap:
Energy, Mines and Resources Canada,
1989. National Topographic Series 116B/3

Reviewed By: MG

Drawn By: GC

Date Issued: October, 2003

Project Number: 22-680

File Name: 22680_Dawson_Fig1_Final.WOR

Revision: 0

Dawson
Known Well Locations

Yukon Groundwater and Ground Heat
Potential Inventory

4.5.3 Dawson City Topography and Hydrology

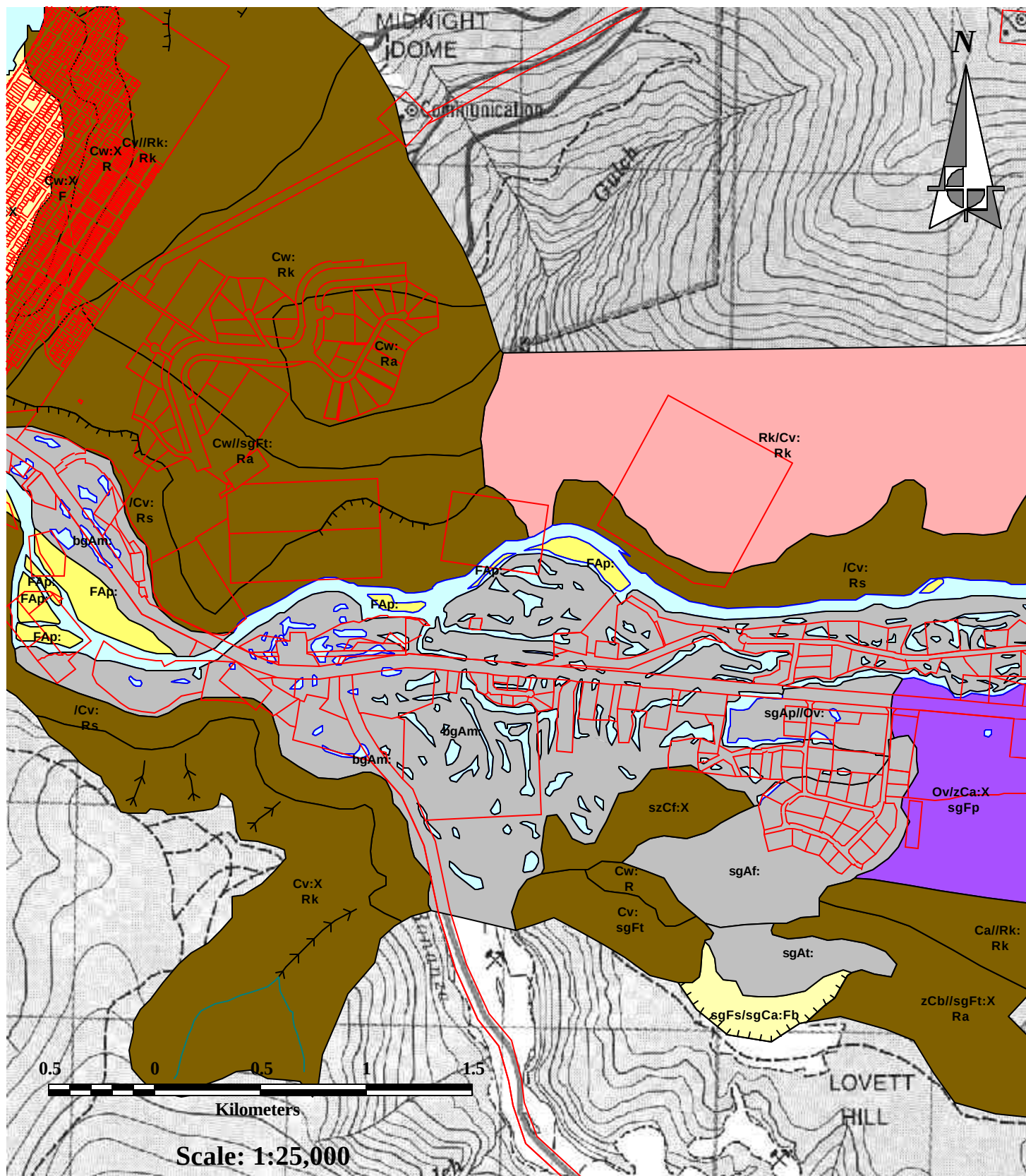
Dawson City is located near the west end of the Klondike River Valley on the bank of the Yukon River near its confluence with the Klondike River. The Klondike River Valley is relatively steep-sided and it is vegetated by boreal forest. Within the valley floor sand and gravel deposits are interspersed with peaty deposits within marshy areas. These fine-grained organic-rich deposits are frequently ice rich (permafrost) and are referred to as “black mucks”. These conditions are typically associated with permafrost. Many of the unconsolidated sediments near Dawson City were disturbed by placer mining operations during the first half of the twentieth century. As a result, long sinuous gravel and rock piles cover most of the area. Pondered water is present among some of the rock piles. Surface water originating on adjacent slopes drains toward the Yukon River and the Klondike River.

4.5.4 Dawson City Geology

A terrain interpretation of the Dawson City area is shown on Figure 4.4-2. The city is situated on low alluvial terrace at the confluence of the Klondike River and the Yukon River. The downtown area is bounded to the east by colluvium-covered bedrock slopes of the Midnight Dome. The city extends further to the east, occupying portions of the Klondike River Valley.

Soil underlying the downtown varies from unfrozen alluvial sand and gravel (near the mouth of the Klondike River) to ice-rich organic sediments (near the north end of town). Surficial soil within the Klondike River Valley consists primarily of serpentine cobble and gravel piles that were placed during gold dredging operations. The tailings piles are interspersed with numerous small ponds. The area east of Callison Subdivision has not been mined and is underlain by frozen organic sediments overlying alluvial gravel. Permafrost is developed beneath the downtown area to considerable depth. Areas that have been mined for placer gold are unfrozen. The most recent surficial geology map of the Klondike is by Duk Rodkin at a scale of 1:250,000 scale (1996).

The escarpments that bound the city and the Klondike River Valley are typically exposed bedrock and are frequently capped with alluvial sand and gravel terraces. Many of these terraces (e.g., Jackson Hill south of the Callison Subdivision area) have been mined for placer gold. The bedrock is described as variably altered and foliated, basalt, diorite and gabbro, chloritic greenstone, amphibolitic greenstone and amphibolite of the Anvil Formation. The north end of the town is underlain by muscovitic and/or chloritic quartzite and quartz-muscovite-chlorite schists of the Klondike Schists (Gordey and Makepeace 2000).



LEGEND: Primary Surficial Material

- A - Anthropogenic
- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- O - Organic
- R - Bedrock

- Gully
- Escarpment
- Landslide
- Extent of interpretation

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Drawing:
Energy, Mines and Resources Canada,
1993 National Topographic Series 116B/3
Reviewed By: FKP
Drawn By: NS/FKP
Revised: June 2003
Project Number: 22-680
File Name: 22680_Dawson_surfgeo.WOR
Revision: 0

**Town of Dawson City
Terrain Interpretation**

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Lee

Figure No.

4.5-2

4.5.5 Dawson City Hydrogeology

Locations of identified water wells in Dawson City appear on Figure 4.4-1. Most identified wells are completed within a shallow unconfined aquifer. Dawson City is within an area of discontinuously developed permafrost and permafrost is developed beneath much of the city. It is likely that shallow groundwater flow in the Klondike River Valley above the zone of permafrost is mainly horizontal and that groundwater flow beneath the permafrost is more complex. The permafrost is likely to act hydraulically as a confining layer for shallow and deep aquifers and constrain vertical groundwater flow.

Dawson City is located on the floodplain of the Yukon River and is protected by a dyke that is located near the waterfront. Accordingly, the water table beneath the city is expected to be shallow. The presence of a shallow water table is suggested by the presence of ponded water between tailings piles within the Klondike River Valley. The shallow unconfined aquifer beneath Dawson City is recharged from surface runoff and infiltration from nearby streams and rivers (Klondike River, Yukon River, Bonanza Creek, Bear Creek, Hunker Creek, and Rock Creek). It is inferred that, in general, the direction of groundwater flow beneath Dawson City is toward the Yukon River.

4.5.6 Dawson City Community Visit

Gartner Lee visited Dawson City on December 13, 2003. During the visit, Messrs. Martin Guilbeault and Dennis Lu of Gartner Lee met with the following community members:

- Mr. Norm Carlson of Dawson City provided information regarding the City's three community wells. Operators with the Dawson City Public Works provided access to the community wells and assisted with the field monitoring.
- Gartner Lee collected groundwater field measurements from three wells that are operated by Property Management Corporation (PMC). Mr. Mike Fraser of PMC provided information about the wells and facilitated access to them. Most information consisted of drawings showing well locations. Minimal information was available concerning the construction details of the wells. These wells included:
 1. the Klondike Valley Firehall well. The well is located at the rear of the building and the firehall is equipped with a reservoir.
 2. the Klondike Valley Grader Station well. The well is located near the front of the building. The groundwater is reported to be of poor aesthetic quality. The distribution system is equipped with a softener.
 3. the Dawson City Airport well. An old well was identified inside the building beneath the customs office. Water quality measurements were collected from the men's washroom tap.

Results of groundwater field measurements completed during the December 13, 2002 visit are summarized in Table 4.5-2.

Table 4.5-2 Dawson City Groundwater Field Parameters Measured on December 13, 2002

Location	Temp.(°C)	pH	Electrical Conductivity (µS)	Hardness	Comments
PW1	3.0	6.55	392	Hard	Municipal supply well
PW2	3.0	6.60	299	Hard	Municipal supply well
PW3	2.5	7.01	250	Hard	Municipal supply well
Highways Maintenance Complex	6.4	6.88	490	Soft	Sample taken inside building after distribution system
Airport	4.0	6.52	291	Hard	

4.5.7 Dawson City Municipal Water Supply

Dawson City is reported to be the first community in the Territory to have its water supplied by wells. Intera (1975) reports that community wells were installed as early as 1903. Historically, municipal water was also obtained from a shallow "infiltration" well that was located approximately 20 m from the Klondike River and from water intakes that were located near the bottom of the Yukon River.

Dawson City currently obtains water from three municipal wells (designated as wells PW1, PW2 and PW3) that are located west of Front Street between Church and Turner Streets. These wells are completed at a depth of approximately 21 m beneath the flood-control dyke that is between the city and the Yukon River. Wells PW2 and PW3 have operated since April 1994. Well PW1 has operated since November 1996. Electrical controls and instrumentation for the wells are housed in a pump-control building that is adjacent to well PW2. Water from the wells is pumped to reservoirs at the Reservoir Pumphouse, where it is heated during winter, chlorinated and pumped into the city's piped distribution system. The "loop" distribution system consists of several loops that allow re-circulation of water. The re-circulation, combined with system bleeding, prevents the water from freezing during winter. Table 4.5–3 summarizes community well details that are identified in the reviewed materials.

Table 4.5-3 Dawson City Community Well Details

Well Name	Completion Date	Total Depth (m below ground surface (bgs))	Static Water Level Range (m bgs)	Estimated Transmissivity (m ² /day)
PW1	1996	21.0	7.31 (1996)	1900
PW2	1992	21.6	3.0 (1992)	1900
PW3	1992	21.3	3.0 (1992)	1900

Note: bgs = below ground surface.

4.5.8 Dawson City Private Water Supply

Private wells are reported to be no longer utilized within Dawson City. THFN representatives also indicated that First Nation's housing developments within the city do not utilize private wells.

Private wells are utilized in the Klondike Valley, including wells at the Dawson City Airport, the Klondike Valley Firehall and the Klondike Valley Grader Station. Several private wells are also reported to be present in the Callison (industrial) Subdivision.

4.5.9 Quality of Groundwater in Dawson City

Groundwater in Dawson City typically contains elevated concentrations of iron and manganese but otherwise meets applicable Canadian Drinking Water Guidelines. Iron concentrations in groundwater that were measured between 1993 and 2000 in the city's municipal wells ranged between 0.009 mg/L (in September 1993) and 1.6 mg/L (in January 1999) (Gartner Lee, 2002). Groundwater from the municipal wells has contained total iron that exceeding 0.3 mg/L (the CDWG guideline) in seven of eighteen samples that were analyzed since 1982. Groundwater from one private well in Dawson City that was sampled in July 1961 had a pH of 7.6, a hardness of 96.5 mg/L and contained 0.02 mg/L of iron and 0.01 mg/L of manganese (Intera 1975).

Table 4.5-4 Selected Averages of Dawson City Groundwater Chemical Analyses (1993 – 2001)

Sample ^a	Number of Samples	pH	Hardness (mg/L CaCO ₃)	Alkalinity (mg/L CaCO ₃)	Iron (mg/L)	Manganese (mg/L)	Reference
raw water supply - combined wells PW1, PW2, PW3	19	7.0	159	106	0.420	0.01	Enkon Environmental Limited 2001

^a Most samples from raw water at the reservoir inlet

Groundwater beneath the Klondike Valley and, in particular, beneath the Callison Subdivision area, is anecdotally reported to be of poor quality due to elevated iron concentrations (B. Albisser, pers. comm. 2002).

4.5.10 Dawson City Groundwater Temperatures

Shallow groundwater beneath Dawson City is likely to be hydraulically connected to nearby surface water bodies. Accordingly, there is a potential for its temperature and chemistry to vary seasonally. Enkon (2002) reported that the temperature of groundwater from the municipal wells (measured in most cases

from the inlet to the reservoir), ranges from 0.2 degrees Celsius in March to 4.8 degrees Celsius in September and October. Groundwater temperatures between December to May are reported to be typically below one degree Celsius.

4.5.11 Dawson City Municipal Groundwater Usage Rates

Between 1992 and 2000, the total annual water consumption in Dawson City varied between 744,700 m³ to 1,106,464 m³ (in 2000). Water consumption is higher during the winter (November through April) than during the summer months. In 2000, the average winter flow rate was 3,706 m³/day while the average summer flow rate was 2,095 m³/day.

4.5.12 Dawson City GSHP Potential

GSHP Type	Potential	Comments
GWHP	Low to Moderate	• Very low groundwater temperatures due to surface water influence. • Some potential for groundwater development in Klondike Valley, but temperatures not identified. • Water quality may be an issue (e.g., iron fouling) in some areas
GCHP	Low to Moderate	• Fine grained, ice rich soils underlie much of the community. • Impact of permafrost on GCHP performance is not known by Gartner Lee • Areas of mined gravel (dredge tailings) may be better suited to GCHP due to saturated gravel. • Shallow bedrock under valley may limit borehole depths
Other	n/a	• Potential for heat pump combination systems for space heating and ground thaw protection (e.g., permafrost maintenance systems under buildings) • Potential for pond loop application in dredge ponds.

Traditional GSHP development may be difficult in Dawson City. However, more innovative opportunities may exist, such as using GSHP technology to keep permafrost frozen under buildings and utilizing the extracted heat for space heating. An alternative application may be to use pond loops (a variant on the GCHP system) that are set in dredge ponds. Although water in dredge ponds is typically cold, it likely represents groundwater flow which could be utilized for a GSHP system. *It is recommended that ESC seek innovate opportunities for GSHP technology applications associated with future developments in Dawson City.*

4.6 Destruction Bay

4.6.1 Destruction Bay Community Description

Destruction Bay is in the Shakwak Valley, between the Alaska Highway and Kluane Lake. The community is 265 km from Whitehorse and 107 km northwest of Haines Junction. A location map showing Destruction Bay and nearby topography appears as Figure 4.6-1. A community profile of Destruction Bay appears in Appendix A.

Destruction Bay is within the traditional hunting and trapping area of the Southern Tutchone First Nation (STFN) people and is home to members of the KFN (KFN). The community is a construction and maintenance post for the Alaska Highway. The population of the community is 51 (Yukon Bureau of Statistics 2003). Electricity for Destruction Bay is supplied by diesel generators.

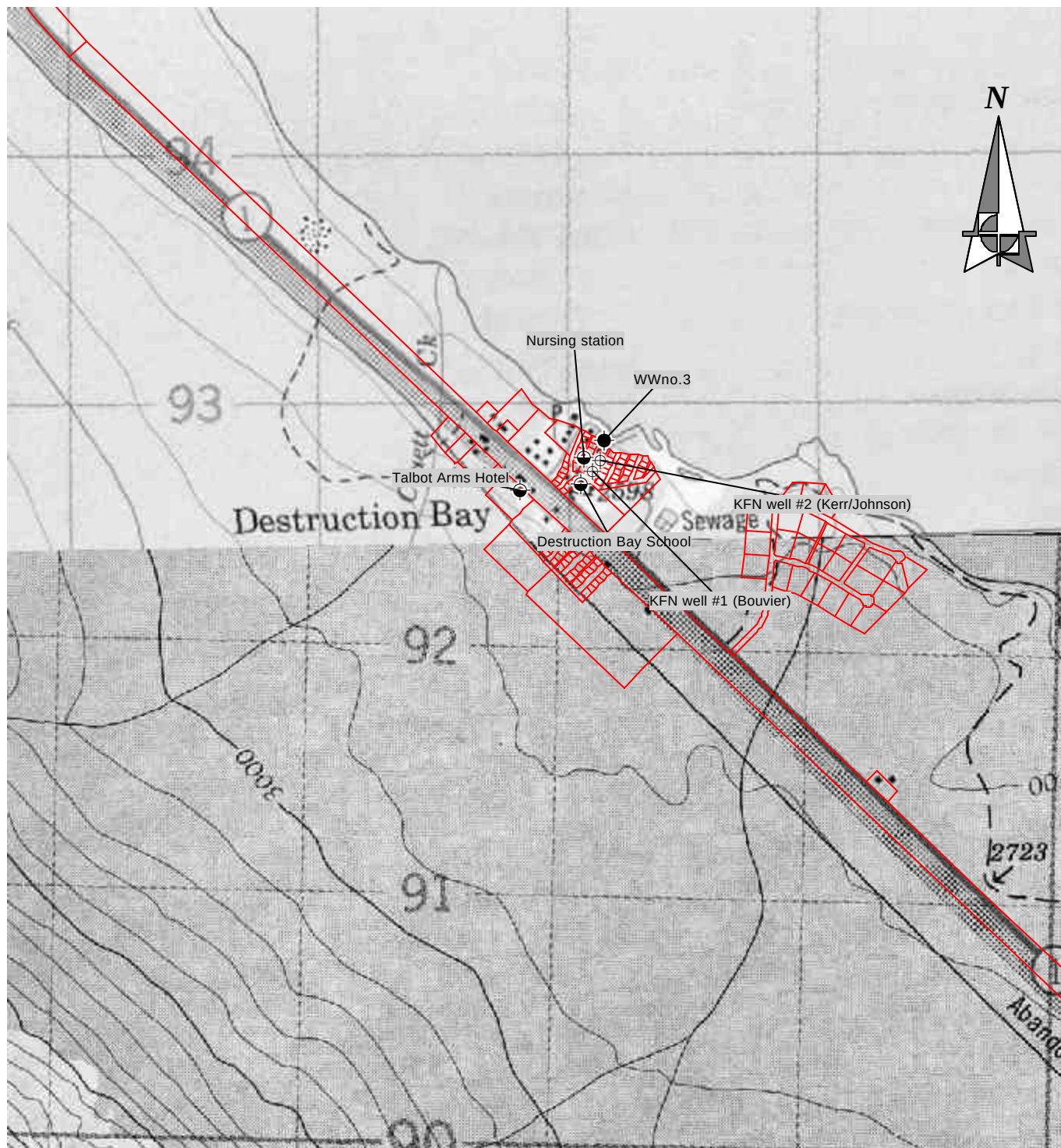
4.6.2 Destruction Bay Climate

Climate normal data for Destruction Bay could not be located. However, climatic data for Burwash Landing (located approximately 20 km northwest of Destruction Bay) are provided in Table 4.6-1.

Table 4.6-1 Climate Normals for Burwash Landing, 1996-2001

Month	Mean Temperatures – Burwash Landing (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-14.84	-26.28	-20.56	7.54
February	-6.66	-21.62	-14.16	5.32
March	-2.28	-18.90	-10.60	5.16
April	5.74	-7.30	-0.76	5.66
May	11.72	-1.88	4.94	23.54
June	18.56	4.78	11.70	53.46
July	19.46	7.02	13.28	62.46
August	17.54	4.46	11.02	42.72
September	9.10	-0.70	4.22	16.32
October	1.28	-9.14	-3.92	24.62
November	-6.84	-17.62	-12.28	9.46
December	-12.70	-24.40	-18.52	13.52
Year	3.34	-9.30	-2.97	269.78

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND:

Identified Water Well Locations
(number of wells)

- Commercial/Institutional
- ⊕ Domestic
- Municipal/Communal

Source of Drawing:
Energy, Mines and Resources Canada,
1981 National Topographic Series 115/G7

Reviewed By: FKP

Drawn By: GC

Revised: October, 2003

Project Number: 22-680

File Name: 22680_DBay_fig1_Final.WOR

Revision: 0

**Destruction Bay
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Gartner Lee

Figure No.

4.6-1

4.6.3 Destruction Bay Topography and Hydrology

Destruction Bay occupies a portion the Burwash Flats on the Yukon Plateau, approximately 20 km southeast of Burwash Landing. Mountains of the Kluane Range (approximately 5 km to the east) rise to elevations above 1,980 m amsl. The nearest surface water body to Destruction Bay is Kluane Lake, which is adjacent to the community. Surface water runoff from adjacent mountains flows toward Kluane Lake.

4.6.4 Destruction Bay Geology

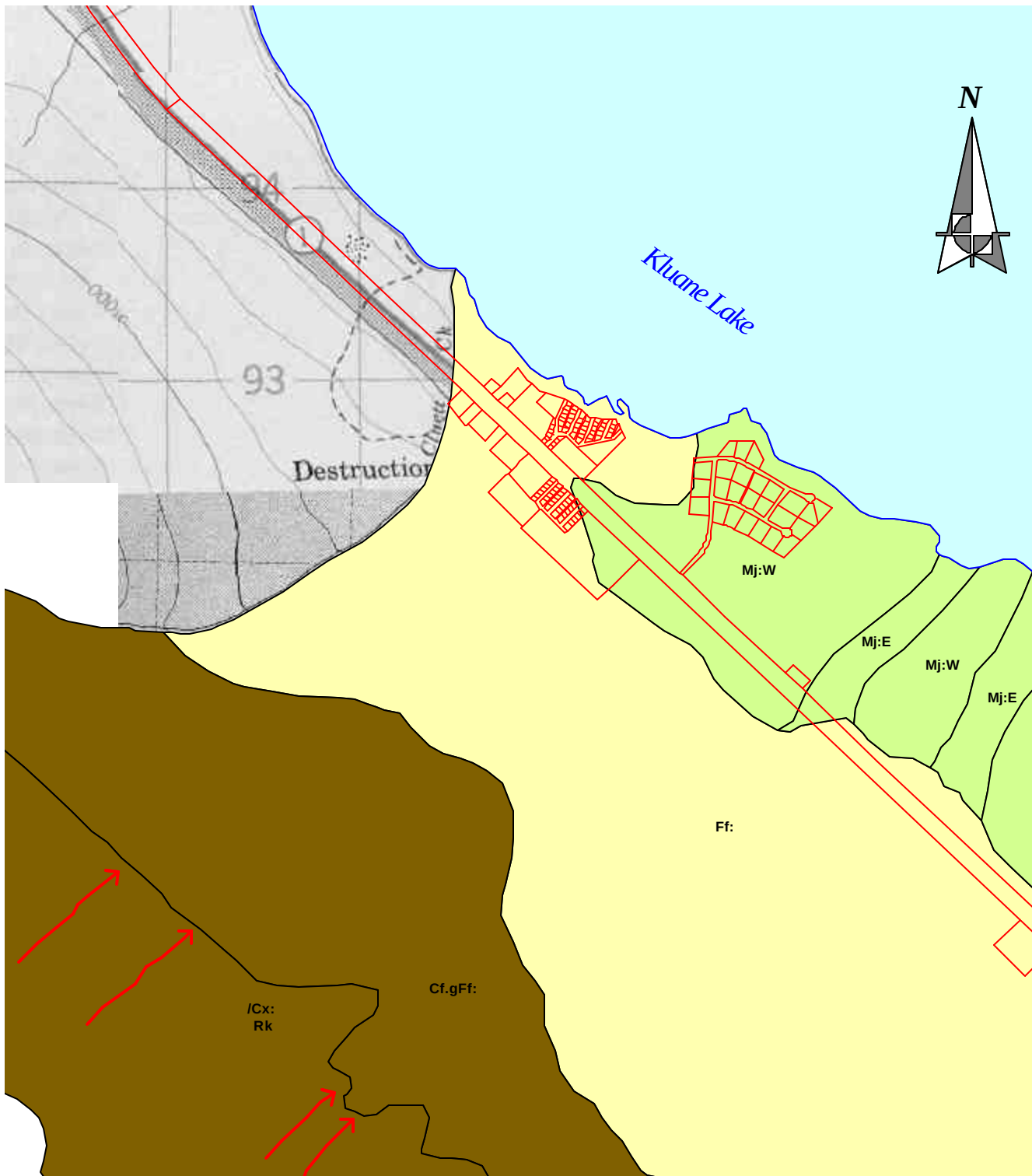
Results of a terrain interpretation of the Destruction Bay area are shown on Figure 4.6-2. The community is located on a gentle slope above Kluane Lake. Approximately 3 km to the southwest, the terrain rises to the mountain slopes of the Kluane Range. The community is located on gravelly alluvial sediments. These sediments cover or partially cover glacial till. This till is exposed in outcrop beneath the south part of the community. The most recent surficial geology map of the area is by Rampton (1978c). It is assumed that at depth, the alluvial fan sediments interfinger with till and lacustrine deposits, providing opportunities for formation of confined aquifers. The aquifer at 30 m depth that is identified in the following sections is likely of this nature.

The nearest bedrock is exposed on the mountain flanks to the west. Bedrock exposed along the toe of the mountains is described as basalt and andesite of the Nicolai Formation (Gordey and Makepeace 2000). Depth to bedrock under the community is reported to be 90 m. However, a test well drilled in 1978 adjacent to the lake to a depth of 164 m did not encounter bedrock (Hydrogeological Consultants Ltd. 1978).

4.6.5 Destruction Bay Hydrogeology

Locations of identified water wells in Destruction Bay are shown on Figure 4.6-1. Most identified wells appear to be completed within sandy and gravelly alluvial sediments. Wells are typically completed between depths of 30 m and 100 m. Some wells are reported to have historically been flowing artesian wells. Some abandoned wells are reported to have become frozen due to permafrost conditions. For this reason, most wells in the community are reported to be equipped with heat trace-tape to prevent freezing.

Intera (1975) reported that several developed aquifers occur beneath Destruction Bay. The shallowest developed aquifer typically occurs between depths of 18 m and 25 m and typically contains (aesthetically) poor water that contains elevated concentrations of iron and hydrogen sulfide. The Highway Maintenance Yard well is completed within this aquifer. Prior to 1975, a well at the Talbot Arms Hotel



0.5 0 0.5 1 1.5



Kilometers

Scale: 1:30,000

LEGEND:

Primary Surficial Material

- C - Colluvium
- F - Fluvial
- M - Morainal (till)



Landslide/mass movement

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Basemap:
Energy, Mines and Resources Canada,
1981 National Topographic Series 115/G7
Reviewed By: FKP
Drawn By: NS/FKP
Revised: June 2003
Project Number: 22-680
File Name: 22680_DBay_01.WOR
Revision: 1

**Destruction Bay
Terrain Interpretation**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No.

4.6-2

was completed in this (shallower) aquifer, but the well was abandoned due to poor (aesthetic) water quality. An 85 m deep flowing artesian well that is completed in a gravel aquifer and a 58 m deep flowing artesian well (at the "forestry buildings" but abandoned in 1975 due to freezing) is also reported to have been installed.

Destruction Bay may be underlain by hundreds of feet of alluvium and glacial till. Mountains of the Kluane range are inferred to provide much of the groundwater recharge to the aquifers beneath Destruction Bay. There is a potential for flowing artesian conditions to be developed in the confined aquifers beneath Destruction Bay due to proximity of the nearby mountains and faults.

4.6.6 Destruction Bay Community Visit

Gartner Lee visited Destruction Bay on December 10, 2003. During this visit, Messrs. Martin Guilbeault and Dennis Lu of Gartner Lee conducted the following visits:

- The Talbot Arms Motel. Some scale and iron stains were observed in the water distribution system. Some community members are reported to obtain drinking water from this well.
- The Destruction Bay School.
- The Destruction Bay Nursing Station. The community nurse lives in an adjacent house. One well supplies water to both the house and the nursing station. The house is equipped with a softener.
- Two KFN private wells, each of which serves two houses. Water from one of the wells is treated using a sand filter.
- Gartner Lee was informed that there are several private wells in a newer subdivision that is between Kluane Lake and the Alaska Highway. However, no subdivision residents were available to provide access to or information concerning these wells.

The results of groundwater field measurements by Gartner Lee on December 10, 2002 are summarized in Table 4.6-2.

Table 4.6-2 Destruction Bay Groundwater Field Variables Measured on December 10, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µS/cm)	Hardness	Comments
School	2.8	7.8	745	Very hard	
KFN houses (1 & 2) Kerr/Johnson	3.5	8.1	648	Very hard	Dark orange staining on appliances
KFN houses (3 & 4) Bouvier	2.9	7.9	742	Very hard	Weak hydrogen sulfide-like odor
Nursing Station / House	5.0	8.3	543	Very hard	
Talbot Arms Hotel	3.7	8.3	589	Very hard	Some hardness stains

4.6.7 Destruction Bay Water Supply

In 2002, residents and users of Destruction Bay obtained water from private wells. Several residents and users obtained drinking water from the private well at the Talbot Arms Hotel.

Historically, two wells supplied municipal water for Destruction Bay until the late 1980s, when these wells were decommissioned due to poor structural integrity. The wells are reported to have been installed for the military in 1943 and to have been between depths of 22 m and 29 m in a sand and gravel aquifer (Intera 1975). The former community water supply system was replaced by private wells, most of which were installed in 1989 (B. Albisser, pers. comm. 2003).

4.6.8 Quality of Groundwater in Destruction Bay

Groundwater quality from most private wells between the Alaska Highway and Kluane Lake appears to be of poor (aesthetic) quality based its visual appearance and hydrogen-sulfide odor. Gartner Lee observed stains within water distribution systems and groundwater from the school and nursing station wells is softened prior to use. Groundwater from the Talbot Arms Hotel private well, which is deeper than the other private wells in the area, is not softened, filtered or otherwise treated.

Selected groundwater quality information relevant to the operation of GSHP systems is summarized in Table 4.6-3.

Table 4.6-3 Characteristics of Destruction Bay Groundwater

Well ^a	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Dissolved Iron (mg/L)	Manganese (mg/L)	Reference
D.P.W. Shop	7.9	-	-	0.25	-	Intera (1975)
Community Well	8.1	269	-	0.17	0.01	Intera (1975)
Water Well No. 3	8.1	273	170	0.33	-	Hydrogeological Consultants Ltd. (1978)

^aExact location of the wells is not identified in the reviewed materials.

4.6.9 Destruction Bay GSHP Potential

GSHP Type	Potential	Comments
GWHP	Low to Moderate	• Low groundwater temperatures and poor water quality. • Potential for better quality and/or higher temperature water in deeper aquifers (if present).
GCHP	Moderate	• Soils underlying community are primarily glacial till • No near surface bedrock to limit borehole depths

Soil underlying the community is mainly glacial till, which limits GWHP potential. Closed-loop (GCHP) systems may be a more viable for this community. If GSHP potential is to be investigated, *it is recommended that deeper exploration drilling be completed to determine if deeper aquifers with warmer and higher quality water are present and which may be suitable for GWHP system development.*

4.7 Town of Faro

4.7.1 Faro Community Description

The Town of Faro overlooks the Pelly River between mountains of the Anvil Range (to the north) and mountains of the St. Cyr Range (to the south). The town is approximately 350 km east of Whitehorse. Road access is provided by an 8 km long road from the Robert Campbell Highway. A location map that shows Faro, the Pelly River and surrounding topography appears as Figure 4.7-1. A community profile of Faro appears in Appendix A.

Faro was developed in 1968 when a community was established to host the employees of the Faro lead-zinc-silver mine. The Faro Mine is located in the Anvil Mountains approximately 22 km northeast of town. The mine operated discontinuously between 1969 and 1997. Town infrastructure was installed to service a population of approximately 3,000. Currently the population of Faro is 363 (Yukon Bureau of Statistics 2003).

Faro is within the traditional hunting and trapping area of the Kaska Dena (or Ross River Dena Council) people, based in Ross River. Electricity for Faro is supplied by the Yukon Electric Corporation (YEC) through the Whitehorse-Aishihik-Faro grid with an emergency diesel generator plant that is located west of town.

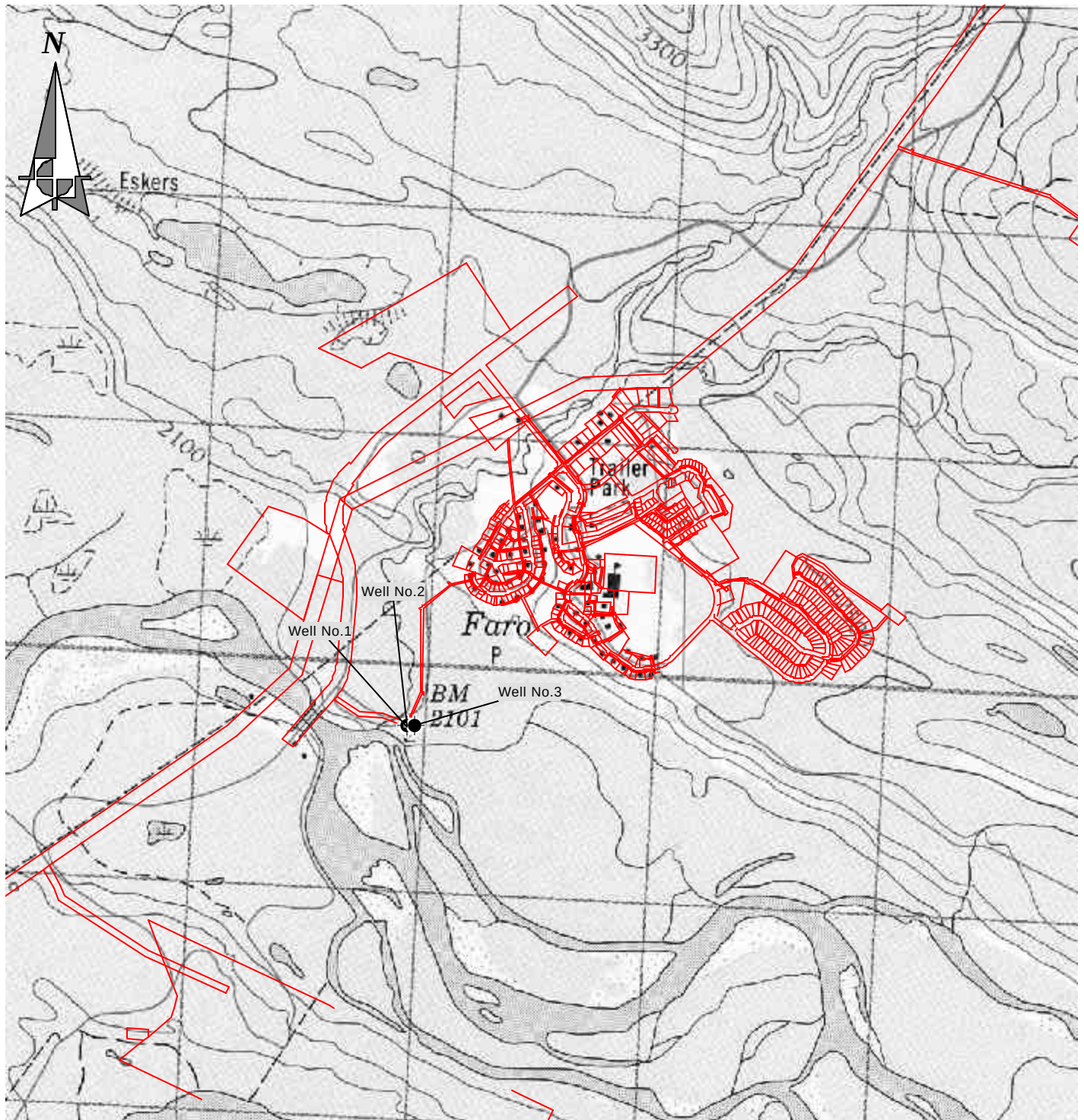
4.7.2 Faro Climate

Climate normal data for Faro for the period 1996 to 2001 are summarized in Table 4.7-1.

Table 4.7-1 Climate Normals for Faro, 1996-2001

Month	5 – Year Mean Temperatures - Faro Airport (Degrees Celsius)			5 – Year Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-16.6	-25.66	-20.72	13.44
February	-8.08	-18.2	-13.16	6.28
March	-2.08	-14.92	-8.38	5.64
April	6.88	-5	0.94	13.22
May	12.94	-0.58	6.8	23.38
June	19.9	7.58	13.74	42.38
July	20.64	9.08	14.9	50.1
August	18.58	6.78	12.72	45.04
September	11.8	1.96	6.92	43.8
October	1.72	-5.9	-2.1	27.42
November	-9	-15.74	-12.4	11.16
December	-8.83	-15.55	-11.90	13.15
Year	3.99	-6.35	-1.05	295.01

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5



Kilometers

Scale: 1:25,000

LEGEND:

Identified Water Well Locations
(number of wells)

● Municipal/Communal (3)

Source of Drawing:
Energy, Mines and Resources Canada,
1973 National Topographic Series 105 K/03
Reviewed By: FKP
Drawn By: GC
Date Revised: October, 2003
Project Number: 22-680
File Name: 22680 Faro_fig1_Final.WOR
0

Faro
Known Well Locations

**Yukon Groundwater and Ground Heat
Potential Inventory**

Gartner Lee

Figure No. **4.7-1**

4.7.3 Faro Topography and Hydrology

Faro occupies a portion the northwest trending Pelly River Valley at elevations between approximately 671 m amsl and 732 m amsl. Mt. Mye (elevation 2,061 m amsl), located approximately 1,600 m to the northeast, is the highest nearby mountain. The nearest surface water bodies to Faro are: a) Vangorda Creek (a tributary of the Pelly River that is approximately 150 m northwest of Faro); b) unnamed tributary creeks of the Pelly River that are located approximately 250 m south of Faro; and c) the Pelly River (located approximately 700 m southwest of Faro). The confluence of Vangorda Creek with the Pelly River is approximately 750 m southwest of Faro.

Permafrost occurs beneath most of Faro. According to Intera (1975), only the lowest terrace along the Pelly River is free of permafrost. The second terrace, where the town is developed, contains abundant permafrost.

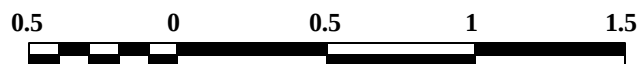
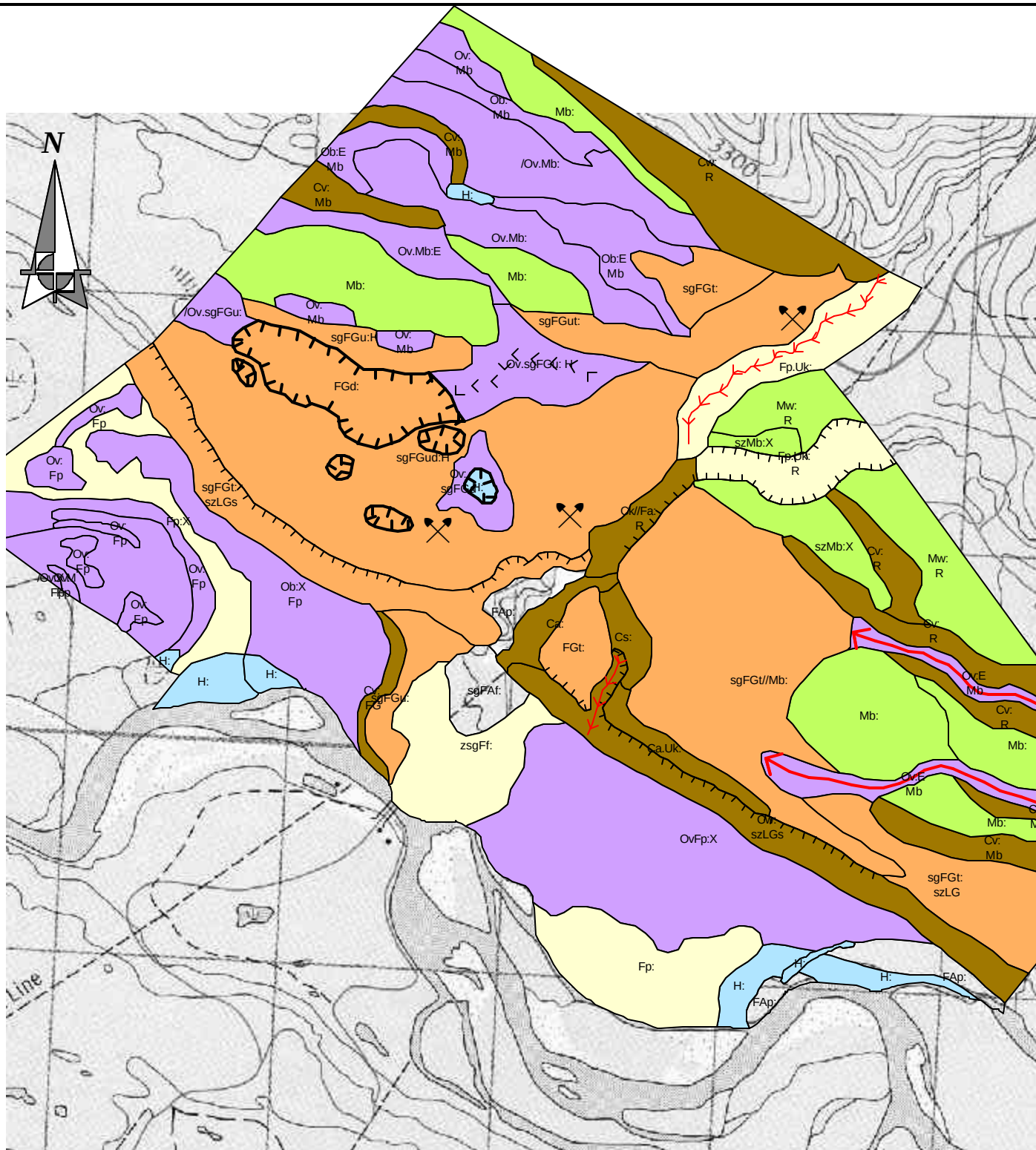
4.7.4 Faro Geology

Gartner Lee reviewed information shown on aerial photographs of Faro and the surrounding area and analyzed terrain features that are apparent in the photographs. The most recent published results of surficial geology mapping for the Faro area that were reviewed are those of Bond (2001). Historic mapping of surficial geology near Faro includes that by EPIC Consulting & Montreal Engineering (Town of Faro 1977). A terrain map of the Faro area appears in Figure 4.7-2.

Faro is situated on a complex assemblage of glacial till and glaciofluvial deposits. The main portion of the town is developed on a glaciofluvial terrace that has been incised by and overlooks the Pelly River. The elevation of the terrace is approximately 710 m amsl. Portions of Faro above elevations of approximately 720 m amsl are underlain by till that overlies bedrock. The town is bounded to the west by the incised channel of Vangorda Creek. Bedrock is exposed along portions of the creek bed.

The results of a 1981 geotechnical investigation of a proposed trailer park in the northwest corner of Faro reported that: a) near-surface soil consists mainly of sandy and gravelly silt till, discontinuous of gravel and sand and peat; b) three of 10 boreholes encountered refusal at depths of 4.0 m, 11.2 m and 6.8 m, suggesting bedrock at these locations; and c) when investigated, permafrost was developed throughout the investigated area (EBA Engineering Consultants Ltd. 1981). Faro's municipal water wells are located south of town on an alluvial plain or low alluvial terrace near the Pelly River.

Hummocky glaciofluvial or ice-contact terrain is west of town and the Anvil Range mine access road. The town's municipal landfill is located in a glacial kettle in this area. Bedrock underlying most of Faro is described as a "locally gritty, muscovite metaquartzite to quartzose schist...contains bands of greywacky, gabbro, phyllite" (Pigage 2001).



Kilometers
Scale: 1:25,000

LEGEND: Primary Surficial Material		Gravel Pit	Extent of terrain mapping
	C - Colluvium		
	F - Fluvial		
	FG - Glaciofluvial		
	H - Water		
	M - Morainal till		
	O - Organic		
		Note: See figure 2.2-1 for the terrain interpretation legend	

Source of Drawing:
Energy, Mines and Resources Canada,
1973. National Topographic Series 105 K/03
Reviewed By: FKP
Drawn By: NS/FKP
Date Revised: October, 2003
Project Number: 22-680
File Name: 22680 Faro_surfgeo.WOR
Revision: 0

Faro Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Figure No. **4.7-2**

4.7.5 Faro Hydrogeology

Locations of water wells in and near Faro are shown on Figure 4.7-1.

In 1968, 11 test holes were drilled in and near Faro to evaluate groundwater potential. The results of the investigation indicate that only the lowest terrace along the Pelly River is permafrost free, that the second terrace (where the town is developed) has abundant permafrost and the third terrace, above the town, is mainly bedrock and unsuitable for groundwater development (Intera 1975). Although it is possible that bedrock aquifers exist beneath Faro, the likelihood that such aquifers are present and details concerning the quality of groundwater within them has not been explored.

The Pelly River Valley near Faro likely contains hundreds of meters of alluvium and till in its deepest parts. The Faro municipal wells are completed within a shallow unconfined aquifer that is developed in unconsolidated sands and gravels near the Pelly River. Additional unconfined sand and gravel aquifers similar the Faro water supply aquifer are likely to be developed within the unconsolidated sandy and gravelly deposits near the Pelly River. A potential also exists for deep confined aquifers to be present within the alluvial sediments that have been deposited within the Pelly River Valley.

The mountains of the Anvil Range likely provide much of the groundwater recharge to the unconfined aquifers that are north of the Pelly River. Groundwater flow within these aquifers is expected to be mainly toward the Pelly River. During times such as the spring freshet when water elevations in the Pelly River are high, the river may act as a groundwater recharge area for nearby aquifers to which it is hydraulically connected. Groundwater conditions (including temperature) in aquifers that are hydraulically connected to the Pelly River or other nearby surface water bodies have a potential to vary seasonally.

4.7.6 Faro Community Visit

Gartner Lee visited Faro on December 11, 2002. During the visit, Messrs. Alex Bath and Gavin Cook of Gartner Lee visited Mr. Pat McCracken of Faro's Public Works Department. Mr. McCracken provided access to the pump house that contains municipal well Nos. 1 and 2. During the visit, Gartner Lee measured the quality of groundwater yielded by the operating municipal wells. At the time of the visit, municipal well No. 3 was on standby and not operating and was not available for monitoring..

The results of Gartner Lee's groundwater field measurements that were collected on December 11, 2002 are summarized in Table 4.7-2.

Table 4.7-2 Faro Groundwater Field Parameters Measured on December 11, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µmho/cm)	Field Hardness	Comments
Municipal well No. 1 or 2	3.8	7.47	528	Very Hard	No groundwater problems were identified other than for deposition of scale; no groundwater temperature difference is reported to exist between operating wells

4.7.7 Faro Municipal Water Supply

Faro obtains water from three municipal wells. Locations of these wells near the Pelly River are shown on Figure 4.7-1. The wells are designated as municipal well Nos. 1, 2 and 3. Municipal wells Nos. 1 and 2 are located in Pumphouse No. 2. Municipal well No. 3 is located in Pumphouse No. 1. All wells are located approximately 700 m south of Faro within the Pelly River flood plain near Vangorda Creek.

Well Nos. 1 and 2 were installed and developed in 1968 using cable tool equipment. The sustainable yield for well No. 2 was estimated to be approximately 59 L/s. The sustainable yield for concurrent pumping using well Nos. 1 and 2 is between 68 L/s and 76 L/s (AES 1979a).

Water from the municipal wells is pumped to two insulated steel reservoirs that are or were located within Faro. In 1991, a third steel reservoir had been constructed but it was not in use. Prior to being distributed, water in the reservoirs was chlorinated, fluoridated and heated to 3.3 degrees Celsius. Historically, permafrost-related breakage of the water mains has been a problem.

Other observations related to the municipal water system include:

- Municipal well Nos. 1 and 2 are approximately 6 m apart. One of the wells is completed at a depth of 15.1 m and screened between depths of 8.9 m and 11.9 m. The other well is completed at a depth of 13.7 m and is screened between depths of 8.1 m and 12.6 m.
- Historically, Faro's water-distribution system has relied on bleeders to prevent freezing. In the 1960s and 1970s, water services were of copper construction. In the 1970s, due to severe corrosion of the original copper services, they were replaced with insulated high-density polyethylene (HDPE) services.
- Stantec Consulting Ltd. (1999) completed a thermal analysis of Faro's water distribution system and assumed that the average temperature of groundwater produced by the municipal wells was 2 degrees Celsius. Stantec (1999) states that the temperature of groundwater at municipal well No. 2 may be 1 degree Celsius higher than that of groundwater at municipal well No. 1.

- Intera (1975) reported that the temperature of groundwater in the municipal wells varies seasonally with the temperature of the Pelly River and that in general, the temperature of the groundwater varies between 1.7 degrees Celsius and 6.1 degrees Celsius.

4.7.8 Quality of Groundwater in Faro

In 1975, Intera analyzed groundwater from the Faro municipal wells and reported that groundwater from the wells met the 1975 Canadian Drinking Water Guidelines. They also reported that in 1968, the temperature of analyzed groundwater from municipal well No. 2 was 3.3 degrees Celsius and the groundwater pH was 7.3.

Selected groundwater quality information relevant to the operation of GSHP systems is summarized in Table 4.7-3.

Table 4.7-3 Characteristics of Faro Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Dissolved Iron (mg/L)	Manganese (mg/L)	Reference
Municipal Wells (June and Dec. 1999)	-	258 – 313	179	0.007 – 0.016	0.0034 - 0.0064	Gibson 1999 in Town of Faro water license renewal

4.7.9 Faro GSHP Potential

GSHP Type	Potential	Comments
GWHP	Low to Moderate	• High yield wells and over sized groundwater production and distribution system • Low groundwater temperatures (due to surface water influence) and water quality issues • Low groundwater development in community area
GCHP	Low	• Soils underlying community are primarily glacial till and unsaturated • Bedrock is near surface limiting borehole depths • Discontinuous permafrost

Soil underlying Faro is mainly glacial till and glaciolacustrine deposits, which limit GWHP development potential. Closed-loop (GCHP) systems maybe a more viable application in this community, however feasibility will be limited by soils with potentially lower thermal conductivity values and limited drilling depths due to near surface bedrock in some areas. However, Faro currently is equipped with an oversized groundwater production and distribution infrastructure. There may be a potential that this oversized

Yukon Groundwater and Ground Source Heat Potential Inventory

system could be used for a district heating/GSHP system. *It is recommended that a feasibility study be completed to review the potential use of the municipal water system for district heating.* Cold winter water temperatures (due to the production wells' proximity to the Pelly River) may limit the usefulness of the water supply for heating. Production wells placed further from the river may potentially be less susceptible to low winter water temperatures. *It is recommended that continuous temperature monitoring of the raw water supply at the wellhead be initiated.*

4.8 Village of Haines Junction

4.8.1 Haines Junction Community Description

The Village of Haines Junction is 158 km west of Whitehorse at km 1,636 of the Alaska Highway near its junction with the Haines Road. Haines Road leads to the port of Haines, Alaska, U.S.A. The village is surrounded by mountains of the Kluane Range to the west, the Ruby Range to the northeast and the Dezadeash Range to the west. Haines Junction was established in 1942 during construction of the Alaska Highway. Currently, the main economy is associated with tourism, due to nearby Kluane National Park. A location map that shows Haines Junction, the Dezadeash River and surrounding topography appears as Figure 4.8-1. A community profile of Haines Junction appears in Appendix A.

Haines Junction is home to members of the Champagne Aishihik First Nations (CAFN). The current population of Haines Junction is 801 (Yukon Bureau of Statistics 2003). Electricity for Haines Junction is supplied by Yukon Electric Corporation (YEC) from the Whitehorse-Aishihik-Faro grid using emergency diesel generators.

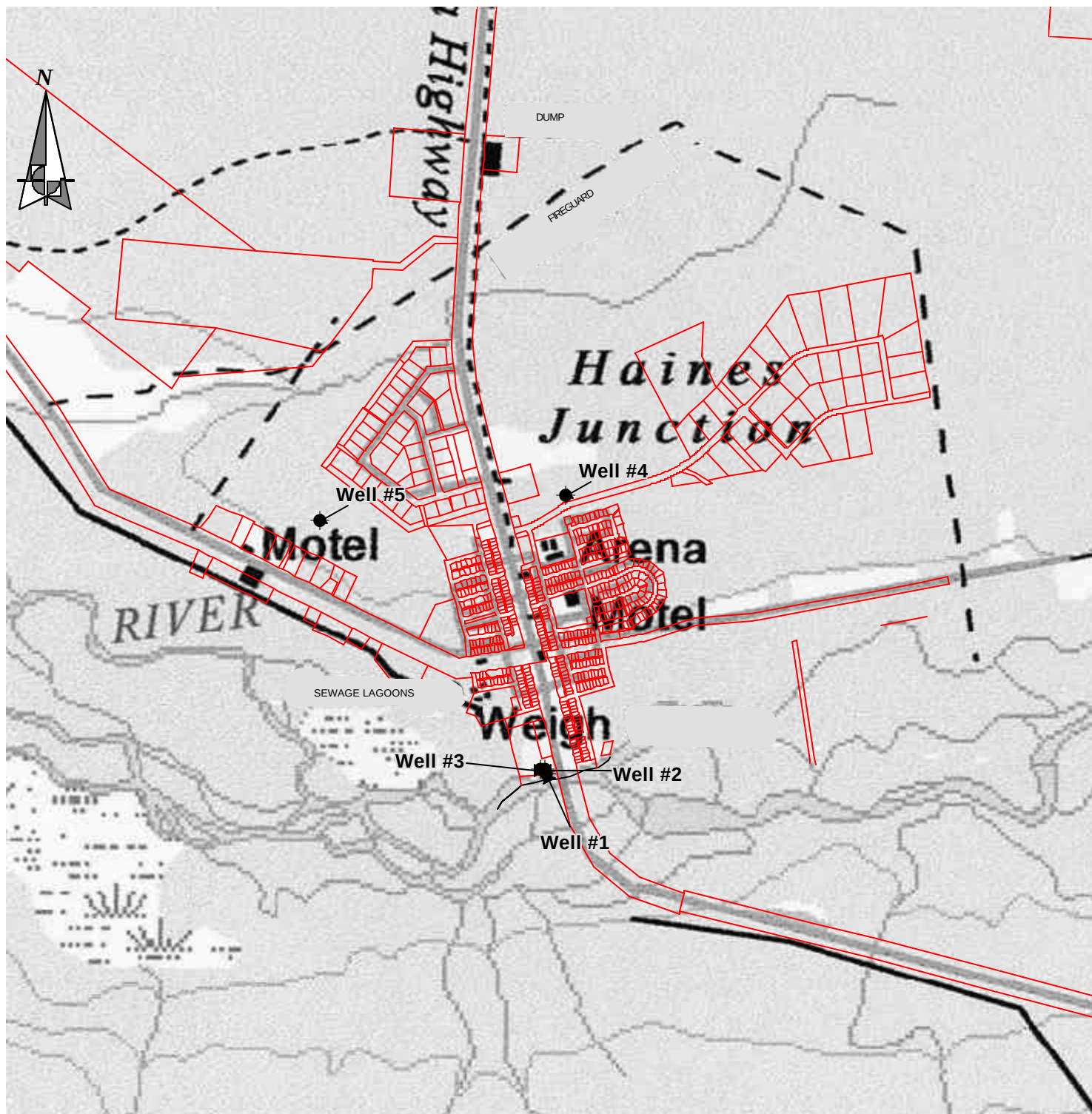
4.8.2 Haines Junction Climate

Climate normals for Haines Junction are presented in Table 4.8-1.

Table 4.8-1 Climate Normals for Haines Junction, 1997-2002

Month	Mean Temperatures – Haines Junction (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-12.46	-25.1	-18.46	43.2
February	-6.4	-20.32	-13.64	18.1
March	-0.46	-13.2	-6.9	9.4
April	7.2	-7.3	-0.04	12.8
May	13.34	-1.9	5.66	11.58
June	20.02	3.94	11.88	45.56
July	20.24	5.6	13.06	43.48
August	19.5	2.96	11.3	36.52
September	12.94	-1.18	5.62	29.08
October	3.96	-7.46	-2.1	34.98
November	-6.36	-15.84	-11.42	38.1
December	-11.36	-22.02	-17.16	51.06
Year	5.01	-8.49	-1.85	373.86

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND:

Known Water Well Locations
(number of wells)

● Municipal/Communal (5)

Source of Drawing:
Energy, Mines and Resources Canada,
NTS Sheets 115A/11, 12, 13, 14

Reviewed By: MG

Drawn By: GC

Revised: October, 2003

Project Number: 22-680

File Name: 22680_HJ_fig1_Final.WOR

Revision: 0

**Haines Junction
Known Well Locations**

Yukon Groundwater and Ground Heat
Potential Inventory

 **Gartner Lee**

Figure No.

4.8-1

4.8.3 Haines Junction Topography and Hydrology

Haines Junction occupies a portion the Takhini Valley along the Shakwak Trench. The Shakwak Trench near Haines Junction is developed between mountains of the Auriol (Kluane) Range (to the southwest), the Ruby Range (to the northeast) and the Dezadeash Range (to the southeast). Mt. Decoeli (elevation 2,332 m amsl, located approximately 15 km to the northwest) is the highest nearby mountain.

The nearest surface water body is the Dezadeash River (a tributary of the Alsek River), located approximately 50 m south of the village.

4.8.4 Haines Junction Geology

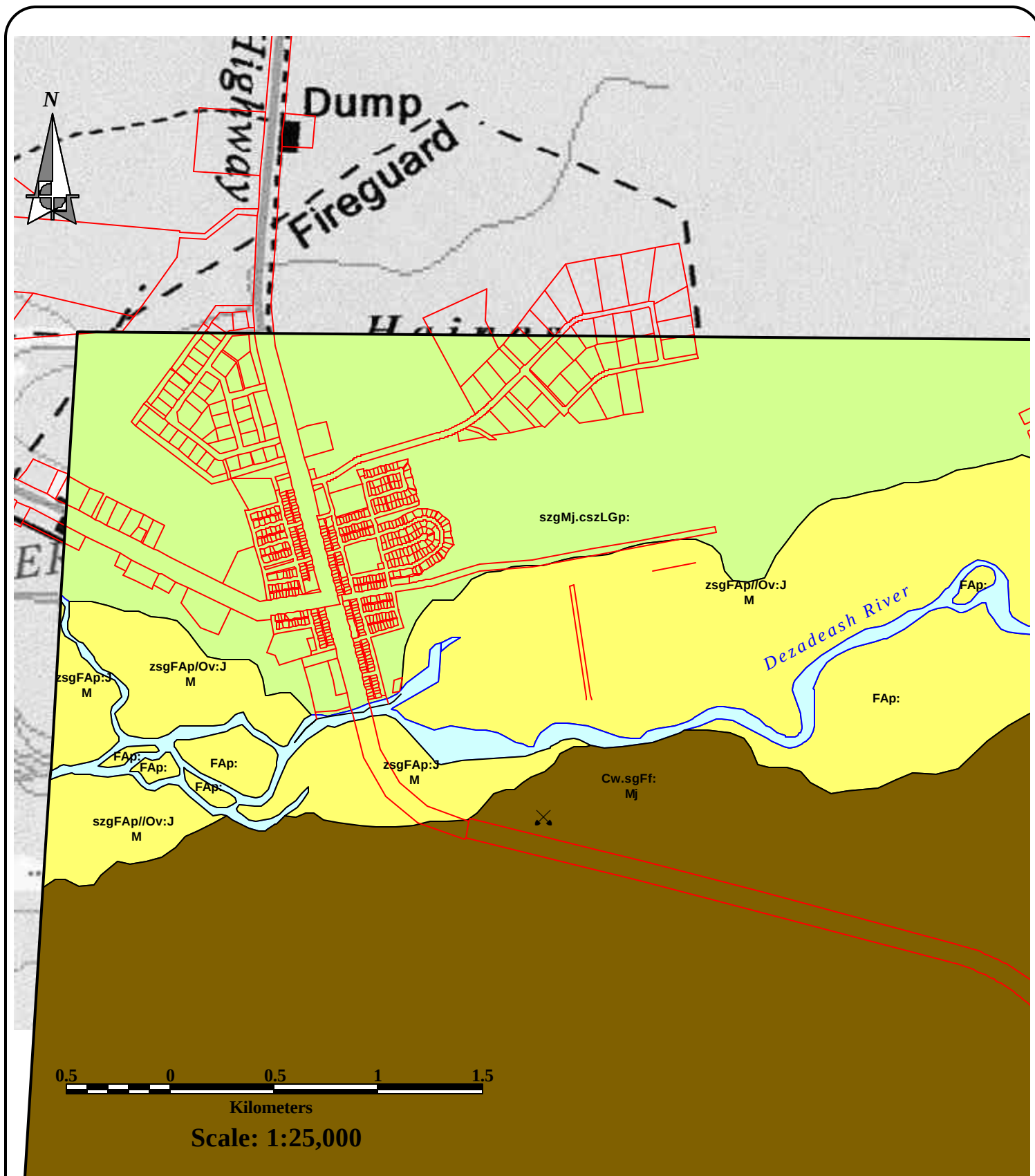
The most recent published surficial geology map of the Haines Junction area that was reviewed is that of Rampton and Paradis (1981). The results of a terrain interpretation that was undertaken during the present investigation appears in Figure 4.8-2.

Haines Junction is located on a gently rolling plain above the Dezadeash River. The south extent of the village is bounded by the flood plain of the Dezadeash River. Native soil underlying much of the village is inferred to consist of a thin or discontinuously developed veneer of sandy and silty glaciolacustrine soil and glacial till. Because the Takhini Valley was the site of numerous glacial lakes before approximately 1800, till underlying the village is likely to be interbedded with glaciolacustrine deposits such as silt.

Information identified on water well logs indicates that thin deposits of coarse-grained fluvial sediments occur beneath the Dezadeash River flood plain. Most of the shallow water wells that are near the river are completed within these deposits. Unconsolidated sediments (mostly till) extend to depths of more than 380 m below the village (Gartner Lee 2002). The nearest bedrock exposures are more than 5 km from Haines Junction.

4.8.5 Haines Junction Hydrogeology

Locations of identified water wells in Haines Junction are shown on Figure 4.8-1. All identified wells are completed in unconsolidated sediments. Most drilled wells range in depth from between 25 m and 200 m. The recently installed community well (Warm Well No. 5), completed at a depth of 370 m, is the deepest water well in the Yukon.



LEGEND: Primary Surficial Material

- C - Colluvium
- FA - Fluvial, active
- M - Morainal (till)

- Gravel Pit
- Extent of Interpretation

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Basemap:
Energy, Mines and Resources Canada,
NTS Sheets 115A/11, 12, 13, 14
Reviewed By: FKP
Drawn By: NS/FKP
Revised: June, 2003
Project Number: 22-680
File Name: 22680_HJ_surfgeo.WOR
Revision: 0

**Haines Junction
Terrain Interpretation**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.8-2**

Intera (1975) reported that by 1975, one or more shallow unconfined aquifers and one or more deep (156 m deep flowing artesian Brewster's Lodge, 111 m deep at the "store") aquifers had been developed. Depth to static water in the "store" well was reported to be approximately 4.7 m. Several private wells in the village in 1975 were completed above a depth of 33 m. In 1974, a community well was completed in gravel at a depth of 13.7 m near the location of the "old" community well. The aquifer in which this well is installed is reported to be hydraulically connected to the Dezadeash River. When analyzed in 1974, the temperature of groundwater in the well was 3.3 degrees Celsius and the water was moderately hard.

Warm Well No. 5 is a flowing artesian well and is inferred to be completed within a deep regional confined aquifer. Recharge to this aquifer likely originates from infiltration of runoff from adjacent mountains. The deep aquifer in which Warm Well No. 5 is completed, has an estimated transmissivity of approximately 23 m²/day. Information regarding the direction of groundwater flow within deep confined aquifers near Haines Junction is not identified in the reviewed materials.

Haines Junction is underlain by a complex system of aquifers that are developed within deposits of interbedded till and glaciolacustrine clays, silts, sands and gravels. These deposits were formed in one or more proglacial lakes, collectively known as Glacial Lake Champagne, that filled the Dezadeash and Takhini Valleys during the retreat of the most recent glaciers some 10,000 years ago. The Warm Well No. 5 aquifer materials may represent alluvial fan or delta deposits that formed near the slope of the Aurial Range south of the current location of the Dezadeash River. These sediments would have been deposited during periods of fluctuating lake levels (Gartner Lee 2002).

4.8.6 Haines Junction Community Visit

Gartner Lee visited Haines Junction on December 11, 2003. During this visit, Messrs. Martin Guilbeault and Dennis Lu of Gartner Lee met with:

- Messrs. Colin Dean and Roy Martinson of the Village of Haines Junction. Messrs. Dean and Martinson provided Gartner Lee with partial construction details, available flow rates and water quality data for the five Haines Junction community wells. Only two of the community wells (well Nos. 3 and 5) are currently operating. Mr. Martinson led an inspection of the well pump houses as well as the village's main pump house and water tower. Mr. Martinson reported that groundwater from (shallow) municipal well No. 1 is very cold; groundwater from (shallow) municipal well No. 2 is silty; and that municipal well No. 4 is not currently in service because a pump was dropped down the well.
- Mr. Harold Kane of CAFN advised the project team that CAFN does not currently operate private wells within Haines Junction.

Results of groundwater field measurements during the community visit by Gartner Lee on December 11, 2002 are summarized in Table 4.8-2.

Table 4.8-2 Characteristics of Haines Junction Groundwater on December 11, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µS)	Field Hardness
Municipal Well No. 5	15	8.9	231	Soft

4.8.7 Haines Junction Municipal Water Supply

In 2003, residents and users of Haines Junction obtained water from two of five municipal (wells No. 3 and No. 5). Municipal well Nos. 1, 2 and 3 are near the shore of the Dezdeash River near Pumphouse No. 2. Municipal well No. 1 (also referenced as Cold Well No. 1) is a shallow drilled well that was installed in 1974. This well yields cold water that requires heating prior to its distribution. Municipal well No. 2 is also a shallow drilled well that is not in use due to excessive volumes of silt in the well. Municipal well No. 4 is near the village's main Pumphouse and reservoir and has been abandoned due to silt problems. Municipal well No. 5 is a deep well that yields warm groundwater.

Haines Junction municipal water is chlorinated prior to being distributed. In early 2003, warm groundwater from municipal well No. 5 was mixed with cold water from municipal well No. 3 in the municipal reservoir prior to being chlorinated and distributed throughout the community

Table 4.8-3 summarizes details regarding the community wells.

Table 4.8-3 Details for Haines Junction Community Wells

Well Name	Completion Date	Total Depth (m bgs)	Static Water Level (m bgs)	Estimated Transmissivity (m ² /day)	Comments
Well No. 1	1974	7.5	-	-	Also referred to as Cold Well No. 1
Well No. 2	1977	257	3	-	Also referred to as Warm Well No. 1
Well No. 3	1980	82.3	13	50-60	Also referred to as Warm Well No. 2
Well No. 5	2002	369.2	Artesian	23	

Notes: bgs = below ground surface.

Additional comments regarding the municipal wells includes the following:

- Well No. 1 is an "infiltration" well that was completed without a screen.
- Well No. 2 was installed in a borehole that was advanced to a depth of 134.7 m. The well was subsequently screened between depths of 77.4 m and 78.3 m using 250 stainless steel screen.
- Well No. 3 was installed between May 29 and June 2, 1980 using an air rotary rig. The well is completed to a depth of 82.3 m. The well is screened with a stainless steel screen between depths of 79.3 m and 82.3 m.
- Well No. 4 has been abandoned but has not been decommissioned.
- Well No. 5 was installed in August and September 2002 to a depth of 369.2 m. The well is screened with 60 slot Johnson-type stainless steel screen between depths of 361.9 m and 369.2 m.

4.8.8 Haines Junction Private Water Supply

Private wells are understood to be no longer utilized within Haines Junction. UMA (1988) provides a location map and a list of 27 private and commercial wells within Haines Junction. It is reported that many private wells in and near Haines Junction were drilled by Tommy Stinson and Midnight Sun. UMA (1988) summarizes some information about well depths and designs which has not been entered into the water well database due to insufficient reporting detail.

4.8.9 Haines Junction Groundwater Quality

Selected groundwater quality information that may be relevant to the operation of GSHP systems is summarized in Table 4.8-4:

Table 4.8-4 Selected Characteristics of Haines Junction Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Iron (mg/L)	Manganese (mg/L)	Reference
Brewster's Motel 500 foot (152.4 m) well (December 1973)	8.3	28	112	0.22	-	Intera (1975), Stanley Associates, 1979
"New" Town Well (June 1974)	7.5	109	103	0.02	-	Intera (1975)
Exp. Farm (July 1961)	7.7	563	-	1.7	0.04	Intera (1975)
Fairdale Store	8.8	-	-	0.48	-	Intera (1975)
Well No. 2	8.51	26	102	0.55	-	Stanley Associates, 1979
Well No. 1	7.5	106	103	0.02	-	Stanley Associates, 1979
Brewster's Well	-	29	95	0.03	0.01	UMA, 1988
Burton Well	-	245	242	0.02	0.02	UMA, 1988

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Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Iron (mg/L)	Manganese (mg/L)	Reference
School Well	-	548	113	0.03	0.24	UMA, 1988
Willow Acres Well	-	1,320	-	0.16	0.38	UMA, 1988
Esso Well	-	167	113	0.12	0.04	UMA, 1988
Well No. 5	8.71	14.4	115	0.75	0.02	Gartner Lee, 2002b
Well No. 3	8.38	32	107	0.06		Stanley Associates, 1980

UMA (1988) noted that groundwater beneath Haines Junction that is obtained from above a depth of approximately 50 m tends to be hard and that groundwater that is obtained from depths of greater than 150 m is generally softer.

4.8.10 Haines Junction Groundwater Temperatures

Shallow groundwater beneath Haines Junction is likely to be hydraulically connected to nearby surface water bodies. The temperature and chemistry of such groundwater that is obtained near surface water bodies may fluctuate seasonally. A summary of identified groundwater temperature data is presented in Table 4.8-5.

Table 4.8-5 Temperature of Haines Junction Groundwater

Well ID	Date	Temperature (Degrees C)	Reference
Well No. 1	-	2.0	UMA, 1988
Well No. 5	Dec. 11, 2002	15	This report
Well No. 3	Dec. 11, 2002	6.5	This report
Mile 1018 well	-	2.5	UMA, 1988

4.8.11 Haines Junction GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	High yield artesian water flowing from Well No. 5 at 15 degrees Celsius represents an exceptionally good potential opportunity.
GCHP	Low to moderate	- Soils underlying community are primarily fine grained - No bedrock near surface to limit borehole depths.

The relatively warm water aquifer encountered by Well No. 5 makes it an obvious candidate for development using GWHP technology. *It is recommended that ESC complete its district heating feasibility study and, contingent on a positive study recommendation, evaluate the potential for heat energy recovery using this resource. Furthermore, it is recommended that this groundwater resource be carefully monitored. and, managed to ensure the long-term sustainable yield of this resource.*

4.9 Keno

4.9.1 Keno Community Description

Keno is located 15 km north of Mayo Lake and approximately 45 km east of the Town of Mayo along the Silver Trail (Territory Highway 11). Keno is located within the mountains of the Gustavus Range.

Keno was developed in the early 1900s when the local silver and lead mine went into production. During the silver boom of the 1950's, the community grew to accommodate workers at nearby gold and silver mines. Keno currently has a population of 25 (Statistic Canada 2001).

Keno occupies part of the southwest slope of Keno Hill in a valley between Keno Hill and Galena Hill. Within the valley, Keno is southeast of Crystal Creek (which flows north around Galena Hill) and north of Lightning Creek (which flows southwest around Galena Hill). A location map showing Keno, Lightning Creek and Erickson Creek and surrounding topography is shown in Figure 4.9-1. A community profile of Keno appears in Appendix A.

Electricity for Keno is supplied by Yukon Energy Corporation (YEC) from its Mayo hydroelectric project.

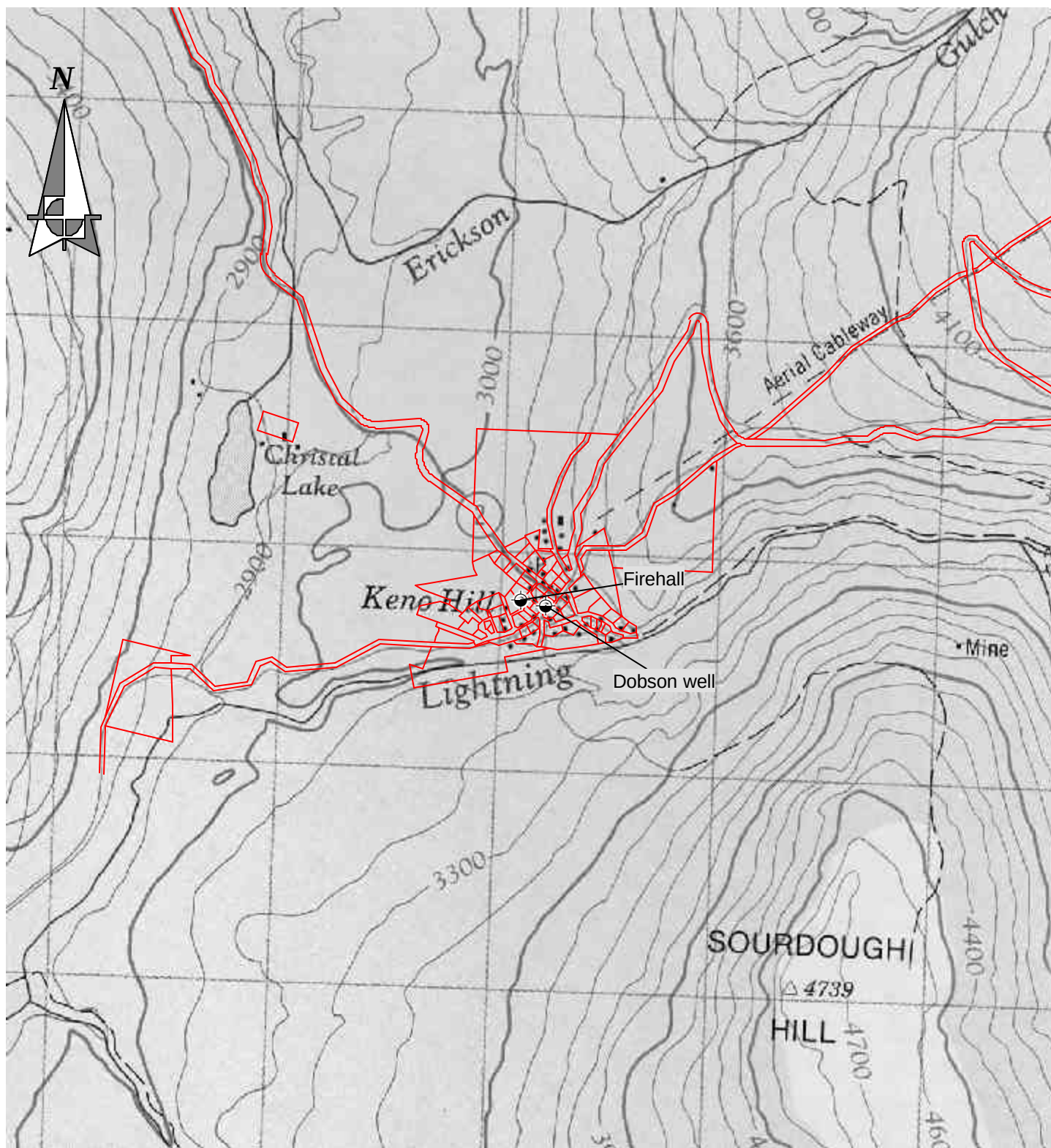
4.9.2 Keno Climate

No climate normal data for Keno could be located as part of this project. However, climate normals for the Town of Mayo (located approximately 40 km east of Keno) are provided in Table 4.9-1.

Table 4.9-1 Climate Normals for the Mayo Airport, 1997-2002

Month	Mean Temperatures – Mayo Airport (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-17.35	-27.88	-22.67	15.38
February	-8.92	-20.83	-14.88	10.75
March	-2.13	-16.35	-9.25	7.78
April	6.88	-6.28	0.32	12.17
May	14.55	1.58	8.08	31.93
June	21.83	7.97	14.92	37.80
July	22.65	9.42	16.05	56.18
August	19.20	7.00	13.12	47.50
September	12.77	1.48	7.13	38.62
October	1.70	-6.37	-2.32	25.95
November	-7.07	-15.75	-11.43	16.60
December	-12.80	-23.64	-18.26	17.36
Year	4.28	-7.47	-1.60	318.03

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5

Kilometers

Scale: 1:25,000

LEGEND:

Identified Water Well Locations
(number of wells)

Commercial/Institutional (2)

Source of Drawing:
Energy, Mines and Resources Canada,
1971 National Topographic Series 105M/14
Reviewed By: FKP
Drawn By: GC
Revised: October, 2003
Project Number: 22-680
File Name: 22680 Keno_fig1_Final.WOR
Revision: 0

Keno
Known Well Locations

Yukon Groundwater and Ground Heat
Potential Inventory

Gartner Lee

Figure No. 4.9-1

4.9.3 Keno Topography and Hydrology

Keno is located in a valley near the southwest toe of Keno Hill at elevations between approximately 930 m amsl and 975 m amsl. The town is located near the north shore of Lightning Creek, which flows east to north near Keno and discharges into Duncan Creek and, eventually in the Mayo River. Keno is surrounded by mountains of the Gustavus Range, of which Keno Hill (elevation 1,848 m amsl, immediately to the East), Galena Hill (elevation 1,445 m amsl, approximately 1 km to the west) and Sourdough Hill (elevation 1,445 m amsl to the southeast) are part.

The nearest surface water bodies to Keno are Lightning Creek (a tributary of Duncan Creek), located approximately 200 m to the south and Crystal Lake, located approximately 1 km to the east.

4.9.4 Keno Geology

Gartner Lee reviewed information shown on aerial photographs of Keno and the surrounding area and analyzed terrain features that were apparent in the photographs. The results of Gartner Lee's terrain analysis are shown on Figure 4.9-2.

The town is located on the west slope of Keno Hill and is bounded by Lightning Creek to the south. Soil in the area is inferred to consist mainly of colluvial till overlying bedrock. Further upslope, the colluvium appears to thin to a veneer of primarily frost-shattered bedrock.

Permafrost appears to be widely developed near Keno and, especially, in till on the lower mountain slopes. Rock dumps from historic mining activities are up-slope from the town. Bedrock beneath the centre of town occurs at a depth of approximately 55 m. Bedrock is described as quartz arenite of the Keno Hill Quartzite (Gordey and Makepeace 2000). When present, permafrost is usually developed within 4 m of the ground surface and has been identified to depths of greater than 40 m.

4.9.5 Keno Hydrogeology

Locations of identified water wells in Keno appear on Figure 4.9-1. Information in the reviewed documents does not identify groundwater depths or groundwater flow directions. However, based on local topography, and assuming that the direction of (unconfined) groundwater flow is influenced by surface topography, it is inferred that the direction of shallow groundwater flow beneath Keno is toward the west.

Static levels of groundwater in the Keno Firehall well (completed in bedrock) are approximately 55 m below the ground surface. This depth coincides with the depth of bedrock and suggests that there is a thick unsaturated or frozen (permafrost) zone of unconsolidated sediments beneath Keno.

Intera (1975) reported that in 1975, a well at the Keno City Hotel that was completed in bedrock was 42.6 m deep. In 1975, water was delivered to community buildings using a truck that obtained water from the 1.6 m deep dug community well which was located approximately 33 m from Lightning Creek.

4.9.6 Keno Community visit

Gartner Lee visited Keno on December 12, 2003. This visit occurred during the evening following a visit to the Village of Mayo, where Messrs. Martin Guilbeault and Dennis Lu of Gartner Lee spoke to Mr. Blair Andre of Property Management Corporation (PMC). Mr. Andre advised Gartner Lee how to access the Keno Firehall well. Unfortunately, the Keno Firehall was locked at the time of the visit and the well's sampling port was not accessible. No community residents were available during the visit to provide access to the well.

Gartner Lee also visited Mr. Geordie Dobson, owner of the Keno Café. Mr. Dobson advised that one private well is located at the Keno Hotel and one other is located in the community. However, the hotel well was not being operated at the time of the visit and the owner of the private well was not available. Accordingly, Gartner Lee could not monitor groundwater quality during the visit.

4.9.7 Keno Municipal Water Supply

Since 1987, most residents and users of Keno have obtained water from a truck that obtains water from a well constructed in 1987 near the Keno Firehall. Drilling of a community well near the Community Hall was started in 1987 prior to drilling of the Keno Firehall well, but this well was abandoned due to equipment problems. Installation details for the Keno Firehall wells are summarized in Table 4.9-2.

Table 4.9-2 Details for the Keno Community Well

Well Name	Completion Date	Total Depth (m bgs)	Static Water (at time of completion) (m bgs)
Firehall	1987	91.46	54.87

Note: bgs = below ground surface.

Additional information not summarized in Table 4.9-2 and which may not be included in the well database is listed below:

- Keno Firehall Well 1 was installed in August 1987 using an air rotary rig by Midnight Sun. This well is constructed to a total depth of 91.4 m (300 ft) using 20.3 cm (8 inch) diameter casing to a depth of 35.6 m (117 feet) and 15.2 cm (6 inch) diameter casing to bedrock at a depth of 54 m (180 feet).
- The borehole for the abandoned community well (that was drilled near the Community Hall) was drilled in July 1987 by Fredelana Enterprises Ltd. using a cable tool rig. Rocks and boulders that were inferred to have been encountered near bedrock are reported to have caused loss of drilling equipment down the hole. No log for this borehole is identified in the reviewed documents.
- A 24 hour pumping test was performed on Firehall Well No. 1 and steady state was not reached. The drawdown after 24 hours of pumping at an average rate of 89.6 L/min was approximately 15 m.

4.9.8 Keno Private Water Supply

According to Keno residents and information in the reviewed documents, there are only two private wells in Keno. One well supplies water to the Keno City Hotel and the other supplies water to a residence. The depths of these wells are not known to Gartner Lee.

4.9.9 Quality of Groundwater in Keno

Some groundwater quality parameters that are relevant to the operation of GSHP systems are summarized in Table 4.9-3:

Table 4.9-3 Characteristics of Keno Groundwater

Well	pH	Hardness (mg/L CaCO ₃)	Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Community Well (May 1970)	7.2	34.0	26	0.48	0.01	Intera (1975)
Hotel Well (June 1965)	7.4	72	48	ND	ND	Intera (1975)
Keno Firehall Well (1987)	-	-	-	-	0.18 – 0.20	YTG (memo)
Keno Firehall Well (2000)	7.9 1	184	n/a	0.09	0.002	YTG (memo)

According to information identified in the reviewed materials, in 1987, groundwater from the Keno Firehall Well met the Canadian Drinking Water Guidelines for all parameters analyzed except for total manganese.

Yukon Groundwater and Ground Source Heat Potential Inventory

Areas of potential environmental concern, with respect to groundwater quality, that were identified included the following:

- the Government of Yukon (YTG) highways maintenance yard and its associated above-ground storage tanks;
- service stations and fuel storage tanks if these have not been properly decommissioned;
- heating oil tanks that are used throughout Keno;
- mining activity wastes; and
- use throughout Keno of conventional septic disposal systems.

4.9.10 Keno Municipal Groundwater Usage Rates

Historic groundwater usage rates for Keno are not identified in the reviewed materials and were not available from the YTG. The community well supplies water to an estimated 10 residents during winter and an estimated 30 residents and additional tourists during summer.

4.9.11 Keno GSHP Potential

GSHP Type	Potential	Comments
GWHP	Low	• Little documented with respect to well yields, groundwater quality or temperature • Groundwater development may be difficult, the community well is deep
GCHP	Low	• Soil is likely mainly coarse grained, colluvium, till and unsaturated • Bedrock near surface is likely to economically limit borehole depths

4.10 Town of Mayo

4.10.1 Mayo Community Description

The Town of Mayo is 56 km east of the Stewart River crossing of the Klondike Highway near the Mayo River at the confluence of the Stewart River. Road access is provided by the Silver Trail, an all-season road from the Klondike Highway (Territory Highway 2) that also provides access to the communities of Elsa and Keno. A map showing Keno, Lightning Creek and Erickson Creek and surrounding topography is shown in Figure 4.10–1. Geographic coordinates of Mayo and elevations of nearby landmarks, along with a community profile, appear in Appendix A.

Mayo was originally established as a river port. Later, it became a service and support centre for nearby silver, zinc and lead mines

Members of the Na-Cho Ny'a'k Dun First Nation comprise 60 per cent to 70 per cent of Mayo's population. Electricity for Mayo is supplied by a Yukon Electric Corporation (YEC) hydroelectric plant. Back-up electricity requirements are provided by a diesel generating plant.

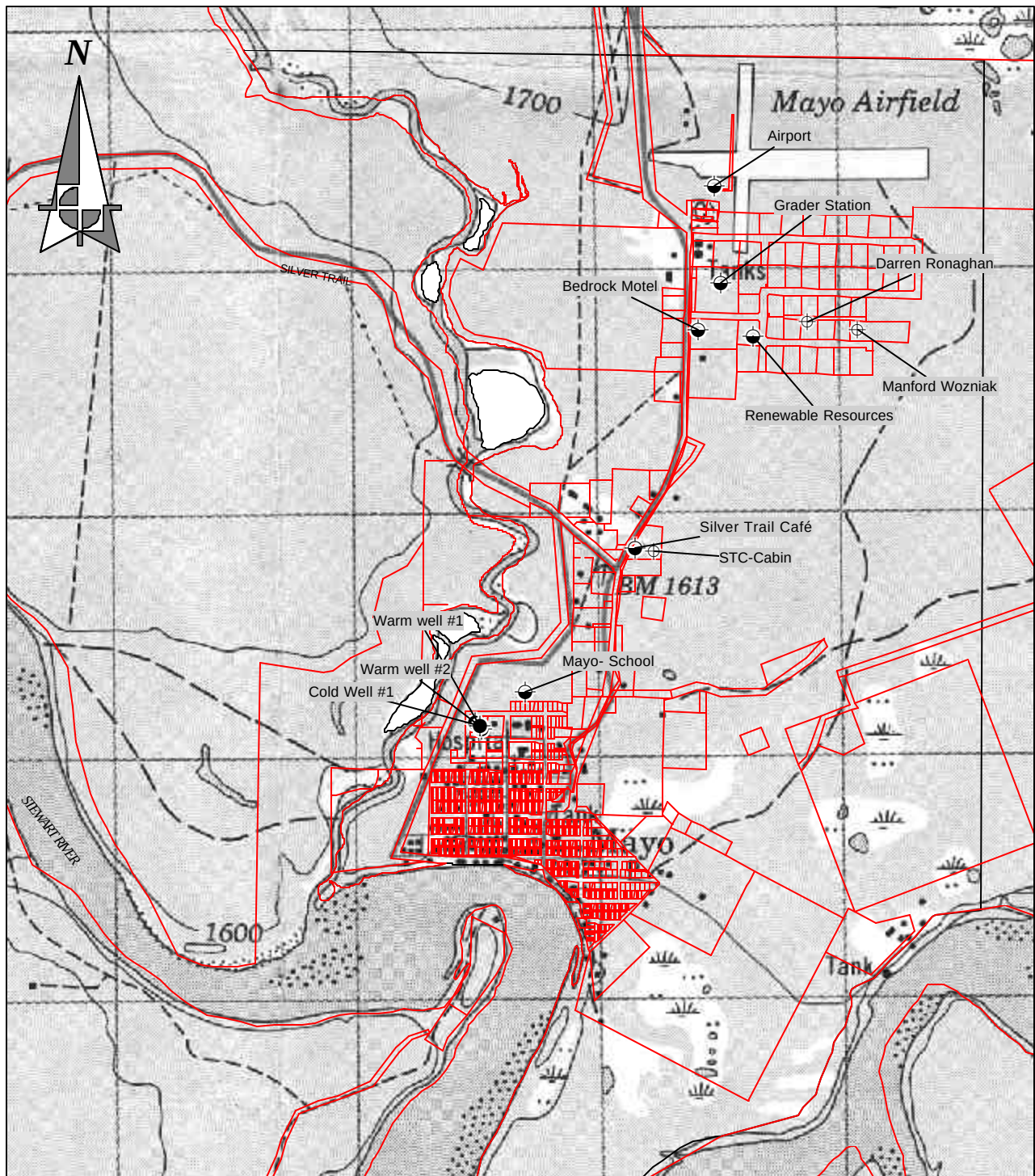
4.10.2 Mayo Climate

Climate normal data for Mayo is presented in Table 4.10-1.

Table 4.10-1 Climate Normals for Mayo, 1997-2002

Month	Mean Temperatures – Mayo (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-17.35	-27.88	-23.6	15.38
February	-8.92	-20.83	-9.7	10.75
March	-2.13	-16.35	-10.2	7.78
April	6.88	-6.28	0.2	12.17
May	14.55	1.58	7.3	31.93
June	21.83	7.97	13.5	37.80
July	22.65	9.42	15.1	56.18
August	19.20	7.00	13.2	47.50
September	12.77	1.48	7.9	38.62
October	1.70	-6.37	-0.9	25.95
November	-7.07	-15.75	-13.1	16.60
December	-12.80	-23.64	-18.2	17.36
Year	4.28	-7.47	-1.5	318.03

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND: Identified Water Well Locations
(number of wells)

- ⊕ Commercial/Institutional
- ⊕ Domestic
- Municipal/Communal

Source of Drawing:
Energy, Mines and Resources Canada,
1971 National Topographic Series 105M/12
Reviewed By: MG
Drawn By: GC
Revised: July 01, 2003
Project Number: 22-680
File Name: 22680 Mayo_01_Final.WOR
Revision: 0

Mayo
Known Well Locations

Yukon Groundwater and Ground Heat
Potential Inventory

Gartner Lee

Figure No. **4.10-1**

4.10.3 Mayo Topography and Hydrology

Mayo is located in the Stewart River Valley near the north shore of the Stewart River and near the confluence of the Mayo River. The elevation of the community is approximately 490 m amsl. The nearest surface water bodies are the Mayo River (located approximately 250 m to the west) and the Stewart River (located approximately 100 m to the south).

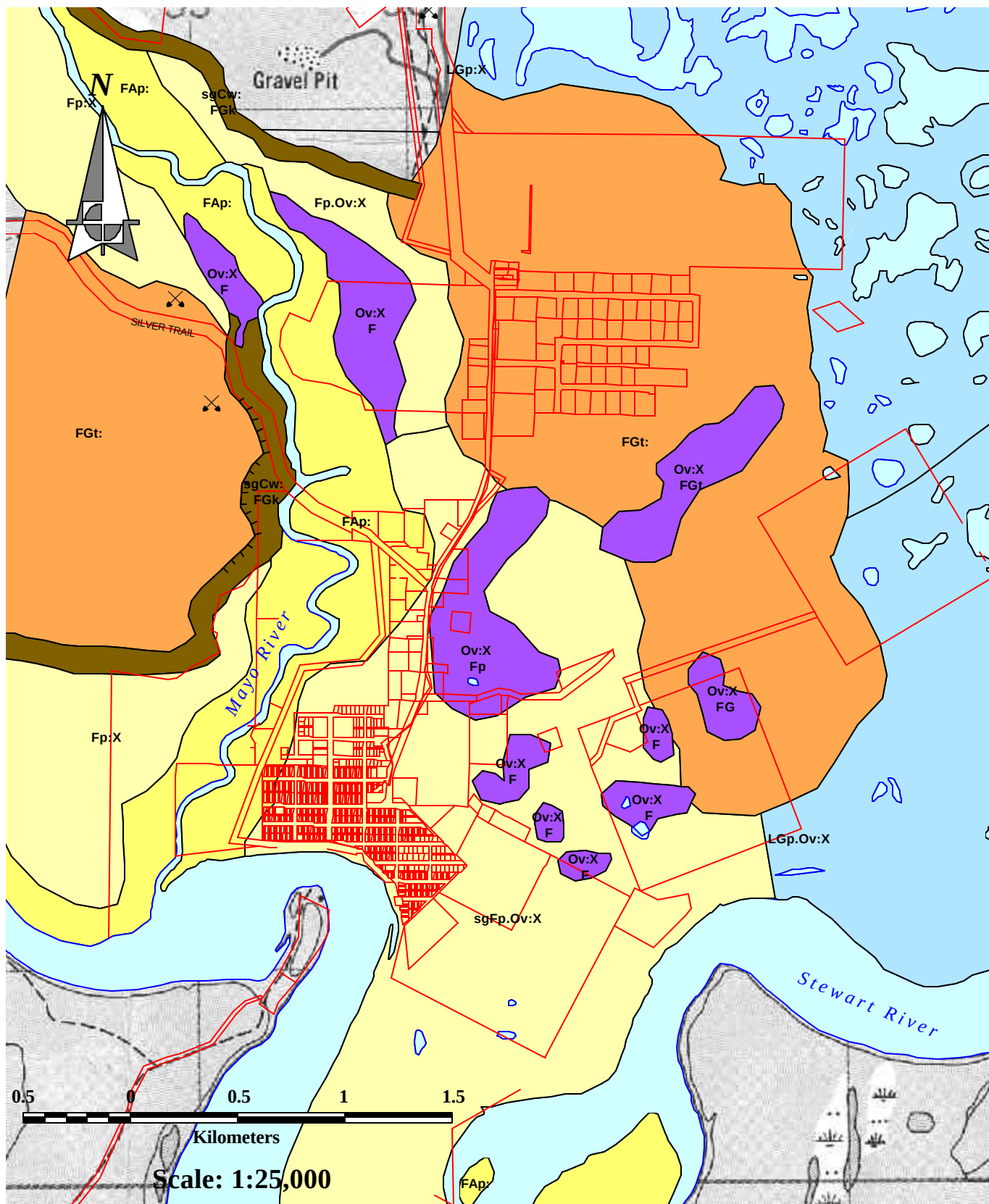
4.10.4 Mayo Geology

A terrain interpretation of the Mayo area is shown on Figure 4.10-2. The town is situated on low alluvial terrace near the confluence of the Mayo and Stewart Rivers. Surface soil is mostly fluvial sand and gravel to a depth of 12 m. These materials overly glaciolacustrine silt and clay and glacial till (MLM Ground-Water Engineering Ltd. 1990). Glaciofluvial terraces (deltas) occur both west and north of the community. Scattered permafrost occurs beneath the community and an extensive area of thermokarst occurs on the glaciolacustrine plain to the east. The most recent surficial geology map of the area is that of Hughes (1979) at a scale of 1:100,000.

Bedrock has been encountered in the town's two deep wells at a depth of 255 m. Bedrock is described as argillaceous sandstone. Regionally, bedrock is described as bedded shale, fine to coarse grained quartz-rich sandstone, grit, and quartz-pebble conglomerate of the Hyland Group (Gordey and Makepeace 2000).

4.10.5 Mayo Hydrogeology

Locations of identified water wells in Mayo are shown on Figure 4.10-1. Most identified wells are completed within a shallow unconfined aquifer that is likely to be hydraulically connected to the Stewart River and the Mayo River. Exceptions are the municipal warm water wells. Static levels of groundwater in shallow Mayo wells range between 3 m and 6 m in depth. Confirmation of the general direction of shallow groundwater flow is not possible using the reviewed information. However, assuming that the direction of unconfined groundwater flow is influenced by surface topography, it is likely that, in general, shallow groundwater flow is toward the Stewart River (beneath the central and east part of Mayo) and toward the Mayo River (beneath the west part of Mayo). The presence of deep confined aquifers beneath Mayo is inferred from flowing artesian conditions at Warm Well Nos. 1 and 2. The source of recharge for this deep aquifer is not known to Gartner Lee.



LEGEND: Primary Surficial Material

- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- FG - Glaciofluvial
- LG - Glaciolacustrine
- O - Organic

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Basemap:
Energy, Mines and Resources Canada,
1971, National Topographic Series 105M/12
Reviewed By: FKP
Drawn By: NS/FKP
Revised: July 2003
Project Number: 22-680
File Name: 22680_Mayo_fig2.WOR
Revision: 0

**Mayo
Terrain Interpretation**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.10-2**

4.10.6 Mayo Municipal Water Supply

In 2002, Mayo obtained municipal water from three municipal wells (designated by the Municipality as Warm Water Well No. 1, Warm Water Well No. 2 and Cold Water Well No. 1). Municipal drinking water is obtained from Cold Water Well No. 1 (completed at a depth of 7.6 m). Water from this well is heated using heat extracted by plate exchanger from warm groundwater from Warm Water Wells Nos. 1 and 2 (completed at an approximate depth of 252 m). Water from the deeper wells is not mixed with the shallow potable water due to water quality issues such as elevated hardness. All three wells are approximately 200 m east of the Mayo River, as shown on Figure 4.10-1.

Intera (1975) reported that in 1975, three municipal wells supplied water to about half of the community. The wells are located near the Mayo River and were installed with a spacing of approximately 15 m. The farthest well from the river is completed at a depth of 12.8 m and the depth to static water in this well is reported to have been approximately 4.8 m. The middle well was installed in 1969. In 1972, fuel inferred to have originated from a fuel tank near the well, was contaminating the middle well, suggesting that the well is completed within an unconfined aquifer. The well nearest the river was installed in 1972. All wells in Mayo that were installed before 1975 are reported by Intera to have been hydraulically connected to the Mayo River. These wells are no longer in use. Table 4.10-2 summarizes details of community wells that were identified in the reviewed materials:

Table 4.10-2 Details for Mayo Community Wells

Well Name	Completion Date	Total Depth (m bgs)	Static Water Level Range (m bgs)	Estimated Transmissivity (m ² /day)
Cold Water Well	Not Reported	Not Reported	Not Reported	Not Reported
Warm Water Well No. 1	1975	255.7	Artesian (70 kPa)	Not Reported
Warm Water Well No. 2	1985	251.7	Artesian (70 kPa)	160

Note: bgs = below ground surface.

Information identified in the reviewed materials which may not be included in the well database is included below:

- Warm Water Well No. 1 was installed by Midnight Sun in October 1975 at a depth of 255.7 m.
- Warm Water Well No. 2 was installed by Hi-Rate Drilling 1985 Ltd. Alberta between May 20 and June 4, 1990. It is constructed using a 273 mm OD steel casing and is screened between depths of 247.2 m and 251.7 m with a Johnson 203 mm (8 inch) diameter 40 slot (0.040 inch slot width) stainless steel screen.

4.10.7 Mayo Municipal Groundwater Usage Rates

In 1993, the measured water demand for Mayo was 900 m³/day. The daily average for a more recent period was 723 m³/day between September 1, 1999 and December 31, 2000. These values are not anticipated to increase significantly in the near future as the population of the community is stable.

4.10.8 Mayo Private Water Supply

According to the Town of Mayo and information in the reviewed documents, private wells are used by residents and users in the outskirts of town, where municipal water is not available. Most private wells are located within the subdivision near the airport. Private wells also supply the Renewable Resources building, the Bedrock Motel, the Mayo Grader Station and the airport. Most of these wells are shallow dug wells that are completed above a depth of approximately 6 m. The Nacho Ny'a'k Dun First Nation community in Mayo receives water from a truck that is filled at the Mayo municipal well. In addition, the First Nation community has installed seven private wells, each of which is reported to be a shallow dug well.

4.10.9 Quality of Groundwater in Mayo

Selected groundwater quality information relevant to the operation of GSHP systems is summarized in Table 4.10-3:

Table 4.10-3 Characteristics of Mayo Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Iron (mg/L)	Manganese (mg/L)	Reference
Cold Water Well	7.22	105	150	0.014	0.002	Village of Mayo, 2000 Water License Renewal application
Warm Water Well No. 2	8.05	206	252	0.60	0.06	MLM Ground- Water Engineering, 1990
Warm Water Well ^a	-	-	-	0.031	0.043	Quanta Labs, 1988

^a Which warm water well is not specified although both warm water wells are completed in the same formation and, therefore, should contain groundwater with similar chemistry.

According to information provided in the reviewed materials and discussions with community members:

- Historically, groundwater in a deep (Wozniak) private well in the Government of Yukon (YTG) subdivision has contained elevated concentrations of arsenic (personal communication with owner) and a treatment system for arsenic has been installed to treat water from this well.
- Sewage in Mayo is disposed to a piped sewage system that discharges to a sewage lagoon west of Mayo and adjacent to the Stewart River. Houses not connected to the municipal system utilize conventional septic tank and leach pit disposal systems.
- Solid waste that is generated at Mayo is disposed in a municipal landfill that is located 4 km from the community in a glacial kettle.
- Regular quality testing of the quality of water in Warm Water Well Nos. 1 and 2 is not tested because it is not used for drinking. Water from the warm water wells is discharged to the Stewart River after it has been used to heat groundwater from Cold Water Well No. 1. This water has been reported by the Town of Mayo to leave the plate heat exchanger at approximately 9 degrees Celsius.
- Warm Water Well No. 1 has experienced corrosion problems since its installation. Gartner Lee (2003) has documented this and has identified possible geochemical reactions contributing to the problem.

4.10.10 Mayo Community Visit

Gartner Lee visited Mayo on December 12, 2002. During this visit, the following tasks were completed:

- Gartner Lee toured the municipal pumphouse with Mr. John Ewing of the Village of Mayo. Mr. Ewing assisted in monitoring of field parameters in groundwater from each municipal well. Mr. Ewing reported some corrosion problems associated with Warm Water Well No. 2 as well as poor well efficiency.
- Mr. Blair Andre of Property Management Agency (PMA) was contacted. Mr. Andre identified the presence of wells at the Renewable Resources Building, the airport and the Mayo Grader Station. Mr. Andre also provided information regarding the Firehall well in Keno and the community well in Stewart Crossing.
- Mr. Neil Salvin of PMC led Gartner Lee through the above mentioned facilities and wells in Mayo. Mr. Salvin also reported that groundwater at the airport is of poor aesthetic quality (poor tasting).
- Mr. Darren Ronaghan, owner of the Bedrock Motel, provided access to the motel's dug well and a private well at his residence and rental property in the YTG subdivision.
- Ms. Bonnie Smith, owner of the Silver Trail Café, provided access to kitchen taps for groundwater monitoring. The precise location of the café well was not identified by Ms. Smith.
- Mr. Manford Wozniak, resident of the YTG subdivision, provided access to his private well (located inside his garage). The water system is equipped with reservoir, an arsenic treatment system and a softener. This well is reported to be the only drilled well in the subdivision.

Yukon Groundwater and Ground Source Heat Potential Inventory

The results of groundwater monitoring by Gartner Lee during the community visit on December 12, 2002 are summarized in Table 4.10-4.

Table 4.10-4 Mayo Groundwater Field Variables Measured on December 12, 2002

Location	Temperature (Degrees C)	PH	Electrical Conductivity (µS)	Hardness	Comments
Warm Well No. 1	15.0	7.95	558	n/a	Smell of hydrogen sulfide
Warm Well No. 2	14.4	7.78	557	Very hard	Smell of hydrogen sulfide
Cold Well No. 1	4.8	7.09	195	Moderate hard	
Mayo Airport	3.2	7.91	626	Very hard	
Silver Trail Café	2.6	6.91	746	n/a	Sand filter
Bedrock Motel	7.0	7.09	773	Very hard	Dug well in basement, water softener
Darren Ronaghan (Lot No. 1015) Well	n/a	7.18	478		Dug well
Darren Ronaghan Well	3.8	7.26	439	Very hard	Dug well
Manford Wozniak Well	2.9	7.2	453	Very hard	Arsenic / Iron problems

Issues of potential concern, with respect to development of GSHP systems, that were identified during the investigations are as follows:

- presence of an abandoned service station and potential for presence of associated contaminated groundwater;
- presence of the abandoned North of 60 Petrol facility near the airport and its associated fuel storage tanks and potential for presence of associated contaminated groundwater ;
- an operating service station and potential for presence of associated contaminated groundwater; and
- presence of heating oil tanks throughout Mayo an potential for presence of associated contaminated groundwater.

Groundwater and subsurface installations that are located hydraulically down-gradient from these areas are susceptible to being contaminated with fuels and solvents. If unlined, the municipal landfill may also represent a potential source of groundwater contaminants.

4.10.11 Mayo Groundwater Temperatures

Daily monitoring of temperature of groundwater from the Municipal Cold Water Well No. 1 in 1999 and 2000 showed seasonal variations between degree Celsius (during winter and spring) to 6 degrees Celsius (during summer). This seasonal temperature variation is inferred to be due to the influence of the nearby Mayo River and Stewart River, which are likely hydraulically connected to the shallow unconfined

aquifer in which the well is completed. According to municipal records, the temperature of groundwater from Municipal Warm Water Well Nos. 1 and 2 is between 14 degrees Celsius and 15 degrees Celsius.

Groundwater temperature data that is identified in the reviewed materials is summarized in Table 4.10-5:

Table 4.10-5 Temperature of Mayo Groundwater

Well ID	Date	Temperature (Degrees C)	Reference
Cold Water Well No. 1	2001	2.8	Village of Mayo Water License Renewal Application
Warm Water Well No. 1	2003	15.0	Gartner Lee Community visit
Warm Water Well No. 2	2003	14.4	Gartner Lee Community visit
Mayo Airport	2003	3.2	Gartner Lee Community visit
Silver Trail Café	2003	2.6	Gartner Lee Community visit
Darren Ronaghan	2003	3.8	Gartner Lee Community visit
Manford Wozniak	2003	2.9	Gartner Lee Community visit

4.10.12 Mayo GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	- Warm water (up to 15 degrees C) produced by Town's warm water wells represents an exceptionally good potential opportunity - Significant water quality issues require careful management (led to failure of previous heat pump systems and water well)
GCHP	Low to Moderate	- Soils underlying community are primarily fine grained - No bedrock near surface to limit borehole depths

The potential for utilizing ground-source energy was identified in Mayo in the early 1980s. In the late 1980's, a GSHP system was installed to supply one of the building groups within the community with ground-source energy. This building group consisted of the curling club, community hall, fire hall, nursing station, RCMP detachment and holding house. The system utilized the existing distribution system for potable water to pump water to individual buildings. Heat was exchanged at each building using technology that was outdated (pers. Comm. Bert Albisser 2003) and which led to system failure

The relatively warm water produced by Mayo's two warm water wells makes it an obvious candidate for development using GWHP technology. Furthermore, this water is currently being used to heat only the municipal water supply using a simple plate exchanger. It is likely that the heat retained by the water that passes across the plate exchanger is suitable for GSHP development for a district heating system. *It is recommended that water well discharge (after down-gradient from the plate exchanger) be continuously monitored. Furthermore, it is recommended that the previous failed GSHP system be reviewed and a new feasibility study be completed regarding utilization of the warm water resource in a GWHP system.*

4.11 Old Crow

4.11.1 Old Crow Community Description

The unincorporated community of Old Crow is near the Porcupine River, which flows west toward Alaska and, eventually, into the Yukon River. The settlement of Old Crow is located near the north shore of the Porcupine River, 1 km west of the confluence of its tributary, the Old Crow River. The Old Crow River drains the Old Crow Flats to the north.

The settlement is approximately 120 km north of the Arctic Circle and is air accessible year round. Mountains of the Old Crow Range are located to the west. A location map that shows Old Crow and surrounding topography is shown in Figure 4.11-1. A community profile appears in Appendix A.

The Old Crow Flats have been inhabited by people for more than 30,000 years. The current population is 262 (Yukon Bureau of Statistics 2003). The present location of Old Crow was and is an excellent location for fishing and hunting and has been a focal point for First Nation's gatherings. The settlement extends for approximately 1 km along the Porcupine River. Approximately 90 per cent of the residents of Old Crow are members of the Vuntut Gwitchin First Nation. Electricity is supplied by a Yukon Electrical Company Limited diesel generating plant.

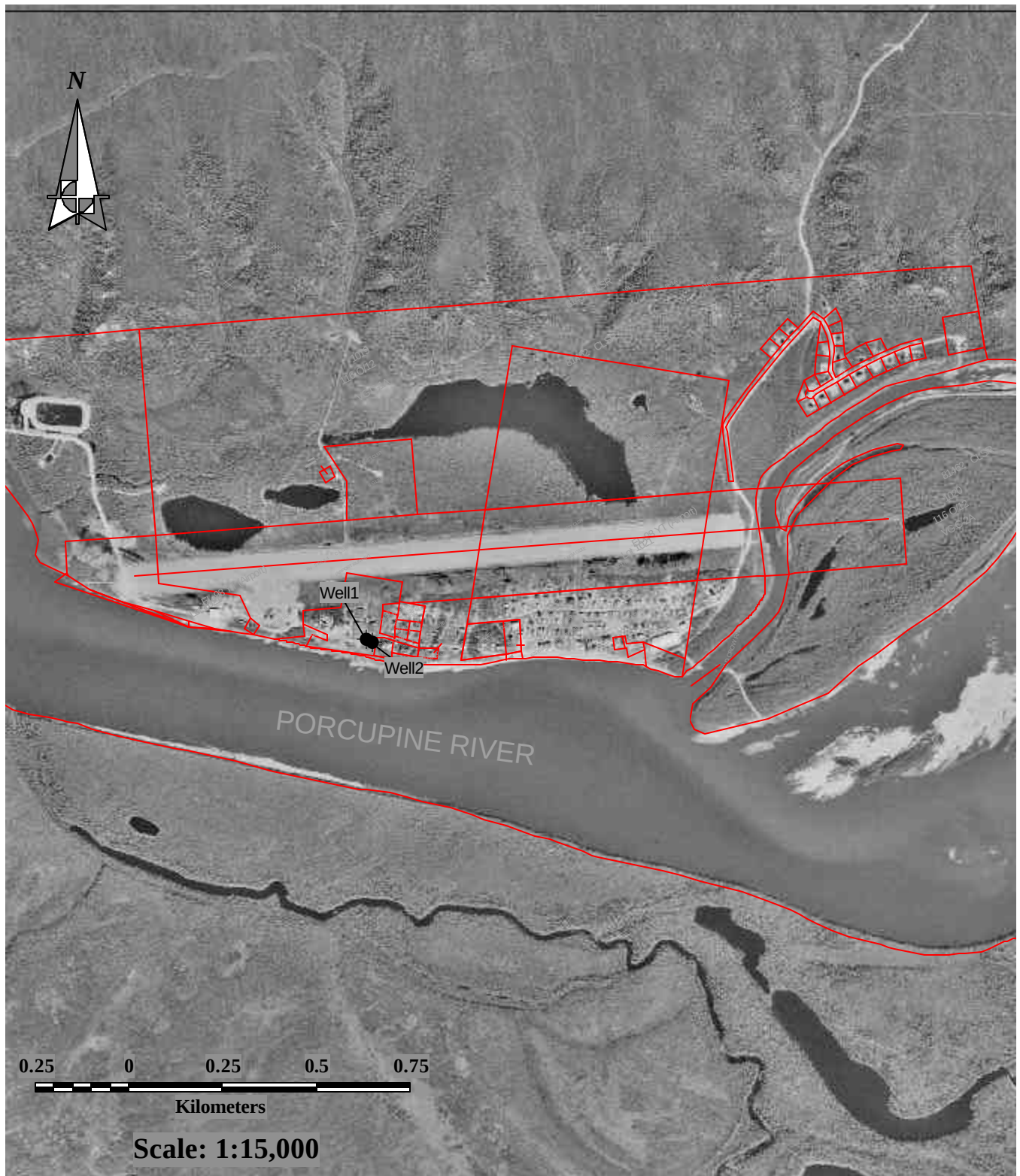
4.11.2 Old Crow Climate

Climate normals for the Old Crow Airport are summarized in Table 4.11-1.

Table 4.11-1 Climate Normals for Old Crow, 1997-2002

Month	Mean Temperatures – Old Crow Airport (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-23.94	-33.74	-28.56	12.74
February	-19.18	-28.04	-23.56	12.88
March	-15.96	-28.32	-22.14	16.62
April	-2.3	-15.8	-9.04	11.1
May	7.8	-3.28	2.28	15.88
June	19.64	7.08	13.36	33.66
July	20.34	8.96	14.66	39.08
August	16.42	6.74	11.6	57.04
September	9.6	0.28	4.96	27.64
October	-5.72	-12.6	-9.2	27.66
November	-17.14	-24.9	-21.04	15.14
December	-20.2	-29.22	-24.62	22.68
Year	-2.55	-12.74	-7.61	292.12

Source: Environment Canada 2002.



LEGEND:

Identified Water Well Locations
(number of wells)

● Municipal/Communal (2)

Source of Basemap:
Basemap derived from one meter
resolution YTG Ortho Photos
Reviewed By: MG
Drawn By: GC
Revised: February 10, 2003
Project Number: 22-680
File Name: 22680_OldCrow_fig1_Final.WOR
Revision: 0

Old Crow
Known Well Locations

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Ltd.

Figure No. **4.11-1**

4.11.3 Old Crow Topography and Hydrology

Old Crow occupies a portion of the east-trending Porcupine River Valley at an elevation of approximately 250 m amsl. The Porcupine River Valley is incised into the Porcupine Plateau south of the Old Crow Flats. The nearest surface water bodies to Old Crow are the Porcupine River (a tributary of the Yukon River) which is immediately south of the Old Crow settlement and the Old Crow River (a tributary of the Porcupine River). The confluence of the Old Crow River with the Porcupine River is approximately 1 km east of the settlement. The settlement is underlain by continuous permafrost to a depth of 63 m (EBA Engineering Consultants Ltd. 1982)

4.11.4 Old Crow Geology

A terrain map of the community is presented in Figure 4.11-2. The settlement is located on a low alluvial terrace and is bounded to the north by a colluvium-covered bedrock terrace. The terrain rises gently above (north of) the escarpment toward Old Crow Mountain. Soil underlying the settlement is inferred to consist primarily fluvial sands and gravels. Finer grained sediments and organic deposits become more abundant between the Old Crow Airport airstrip and the escarpment.

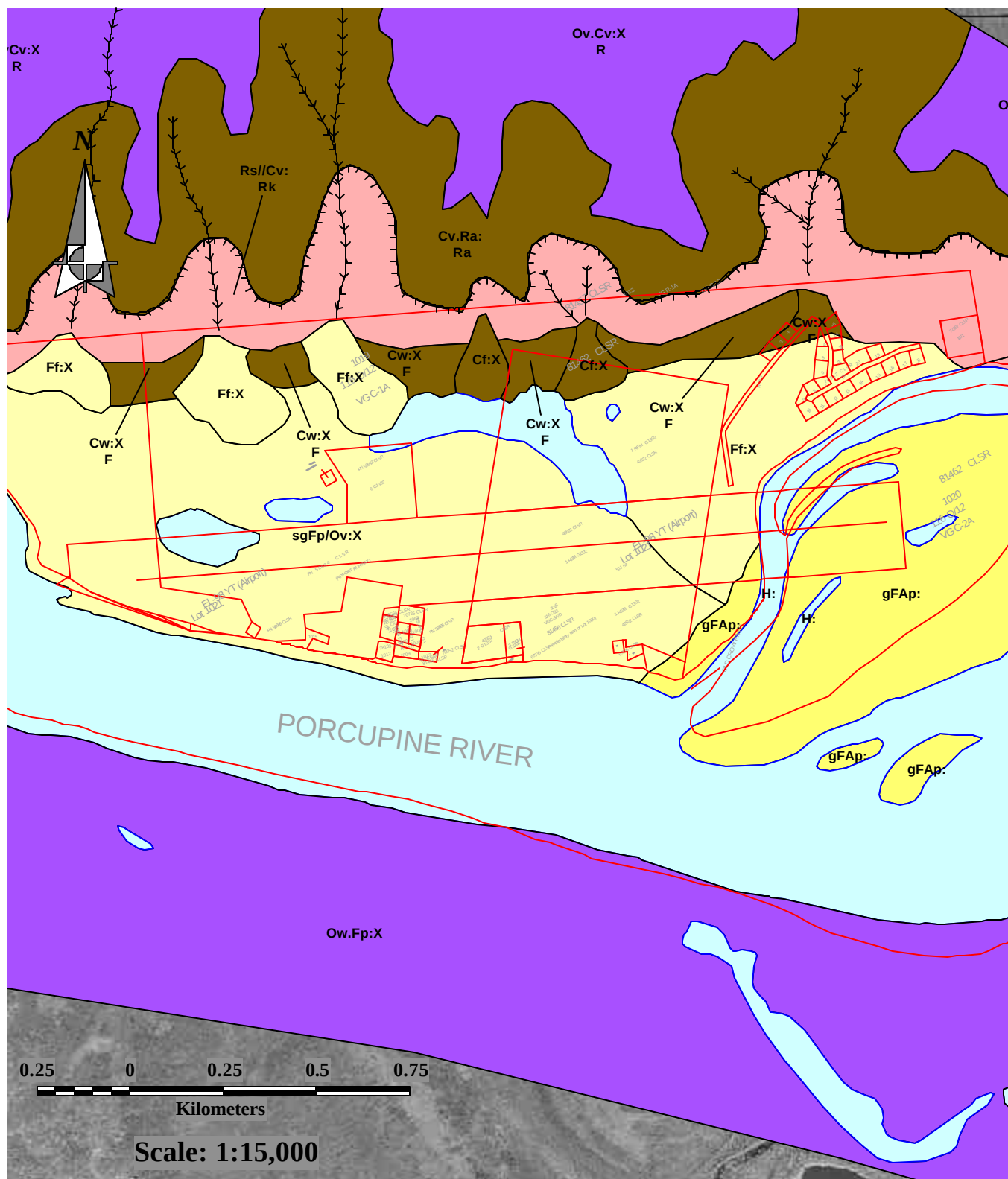
Bedrock exposed along the Old Crow River is described as siltstone and shale of the Kingak Group (Husky Formation) (Gordey and Makepeace 2000). Bedrock was encountered at a depth of 38 m at the community water wells. Bedrock encountered at these locations was logged as sandstone between depths of 38 m and 64 m, interbedded sandstone, siltstone and shale between depths of 64 m and 78 m and limestone and dolomite below a depth of 78 m (EBA 1982).

Old Crow is located within a zone of continuous permafrost. Permafrost has been identified above a depth of 63 m during well drilling and drilling of geotechnical boreholes.

4.11.5 Old Crow Hydrogeology

Locations of identified water wells in Old Crow are shown on Figure 4.11-1. A fractured sandstone/siltstone aquifer is developed at a depth of greater than 60 m. This bedrock aquifer is overlain mainly by unconsolidated clay and silt deposits that are frozen and that are unlikely to contain aquifers with the possible exception of immediately adjacent to and beneath surface water bodies.

The two Old Crow municipal wells (wells OCW No. 1 and OCW No. 2) are completed in the fractured bedrock aquifer. Both wells are flowing artesian wells. Results from a 48 hr pumping test that was performed in 1982 using OCW No. 2 shortly after its installation showed that both well OCW No. 1 and



Originally produced in colour

LEGEND:

Primary Surficial Material:

- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- O - Organic
- R - Bedrock

 Escarpment

 Gully

Note: See figure 2.2-1 for the terrain interpretation legend

Source of Basemap:
Basemap derived from one meter resolution YTG Ortho photos

Reviewed By: FKP

Drawn By: NS/FKP

Revised: February 10, 2003

Project Number: 22-680

File Name: 22680_OldCrow_surfgeo.WOR

Revision: 1

Old Crow Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Lee

Figure No.

4.11-2

well OCW No. 2 are completed within the same aquifer. The test results were used to estimate an aquifer transmissivity of 34 m²/day. A similar test that was performed using well OCW No. 1 resulted in an estimated transmissivity of 17 m²/day.

4.11.6 Old Crow Municipal Water Supply

Until 1982, residents of Old Crow obtained drinking water from the Porcupine River. Two wells (wells OCW No. 1 and OCW No. 2) were installed in 1982. When installed, both wells were flowing artesian wells. Well OCW No. 1 is currently used to supply municipal water to the settlement. Water from the well is distributed using a truck. Well OCW No. 2 was used to extract groundwater and control groundwater conditions at well OCW No. 1 when the well was being installed. Well OCW No. 2 is reported to be frozen and is currently not in use. Neither water temperature nor pressure is reported to be monitored in the municipal well.

Table 4.11-2 summarizes details for the two community wells.

Table 4.11-2 Details for Old Crow Community Wells

Well Name	Completion Date	Total Depth (m bgs)	Static Water Level Range (m bgs)	Estimated Transmissivity (m ² /day)
OCW No. 1	1982	79	Artesian	17
OCW No. 2	1982	96.6	Artesian	34

Note: bgs = below ground surface.

According to information identified in the reviewed materials:

- Well OCW No. 1 is approximately 17 m west of well OCW No. 2.
- Both municipal wells were installed in March 1982 by Midnight Sun using an air rotary rig.
- The borehole for well OCW No. 1 was advanced to a depth of 79 m in bedrock. The well is completed with 152 mm (6 inch) diameter casing at a depth of 79 m and is not screened. The well is equipped with a heat trace cable. In 1982, the rate of artesian flow at the well was 6.1 L/s.
- The borehole for well OCW No. 2 was advanced to a depth of 121.9 m in bedrock. The well is completed with 152 mm (6 inch) diameter casing to a depth of 96.6 m and the well is not screened. In 1982, the rate of artesian flow at the well was 2.3 L/s.

4.11.7 Old Crow Groundwater Quality

Groundwater quality information relevant to the operation of GSHP systems appears in Table 4.11-3.

Table 4.11-3 Selected Characteristics of Old Crow Groundwater

Well	Date	pH	Hardness (mg/L CaCO ₃)*	Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)**	Total Manganese (mg/L)***	Reference
OCW no. 2	1982	7.0	177	143	1.0	0.14	EBA 1982
OCW no. 1	1999	8.05	206	144	0.10*	0.181	YTG 2000a

Gartner Lee 2002a states that from eleven sets of water quality results collected from between 1982 and 2000 at OCW No. 1:

**The concentration of CaCO₃ hardness of analyzed groundwater ranged between 176 mg/L and 211 mg/L*

***The concentration of iron in 5 analyzed samples exceeded 1 mg/L (Gartner Lee, 2002a);*

**** The concentration of manganese in 10 analyzed samples exceeded 0.2 mg/L*

4.11.8 Old Crow Groundwater Temperatures

Gartner Lee did not visit Old Crow as part of this study. According to information in the reviewed materials, the temperature of groundwater from well OCW No. 1 varies between 0.5 degrees Celsius and 2.5. degrees Celsius

4.11.9 Old Crow Community Groundwater Usage Rates

Information identified in the 1998 and 1999 Water Use License MN95-003, Old Crow Sewage Lagoon Reports, indicates a water use rate of 33 m²/week for the metering period between May 24 and May 31, 2000.

4.11.10 Old Crow GSHP Potential

GSHP Type	Potential	Comments
GWHP	Low to Moderate	- Low groundwater temperatures due to permafrost. - Well potentially have adequate yield
GCHP	Low	- Fine grained frozen underlie much of the community. - Impact of permafrost on GCHP performance unknown
Other	n/a	Potential for heat pump combination systems for space heating and ground thaw protection (e.g., permafrost maintenance systems under buildings)

Traditional GSHP development may be difficult in Old Crow. However, more innovative opportunities may exist, such as using GSHP technology to maintain frozen permafrost conditions under buildings and utilizing the extracted heat for space heating. *It is recommended that ESC seek innovative opportunities for GSHP technology associated with future developments in Old Crow. Continuous groundwater temperature monitoring should also be conducted at the community well to help assess the potential for use of groundwater in the community aquifer in GWHP systems.*

4.12 Pelly Crossing

4.12.1 Pelly Crossing Community Description

Pelly Crossing is located near the Pelly River approximately 280 km northwest of Whitehorse and 250 km southeast of Dawson City. The community core is within a meander of the Pelly River immediately south of the North Klondike Highway Bridge and is within the floodplain of the Pelly River. Across Pelly River to the north, topography rises steeply from the river valley in a series of scarps and terraces. The town's Willow Creek and Jon/Ra subdivisions are located north of the town core on a raised alluvial terrace that overlooks the Pelly River. A location map that shows Pelly Crossing and the surrounding topography appears in Figure 4.12-1. A community profile of Pelly Crossing appears in Appendix A.

Pelly Crossing is within the traditional hunting and trapping area of the Selkirk First Nation (SFN). Electricity for Pelly Crossing is supplied by a Yukon Energy Corporation diesel generation plant.

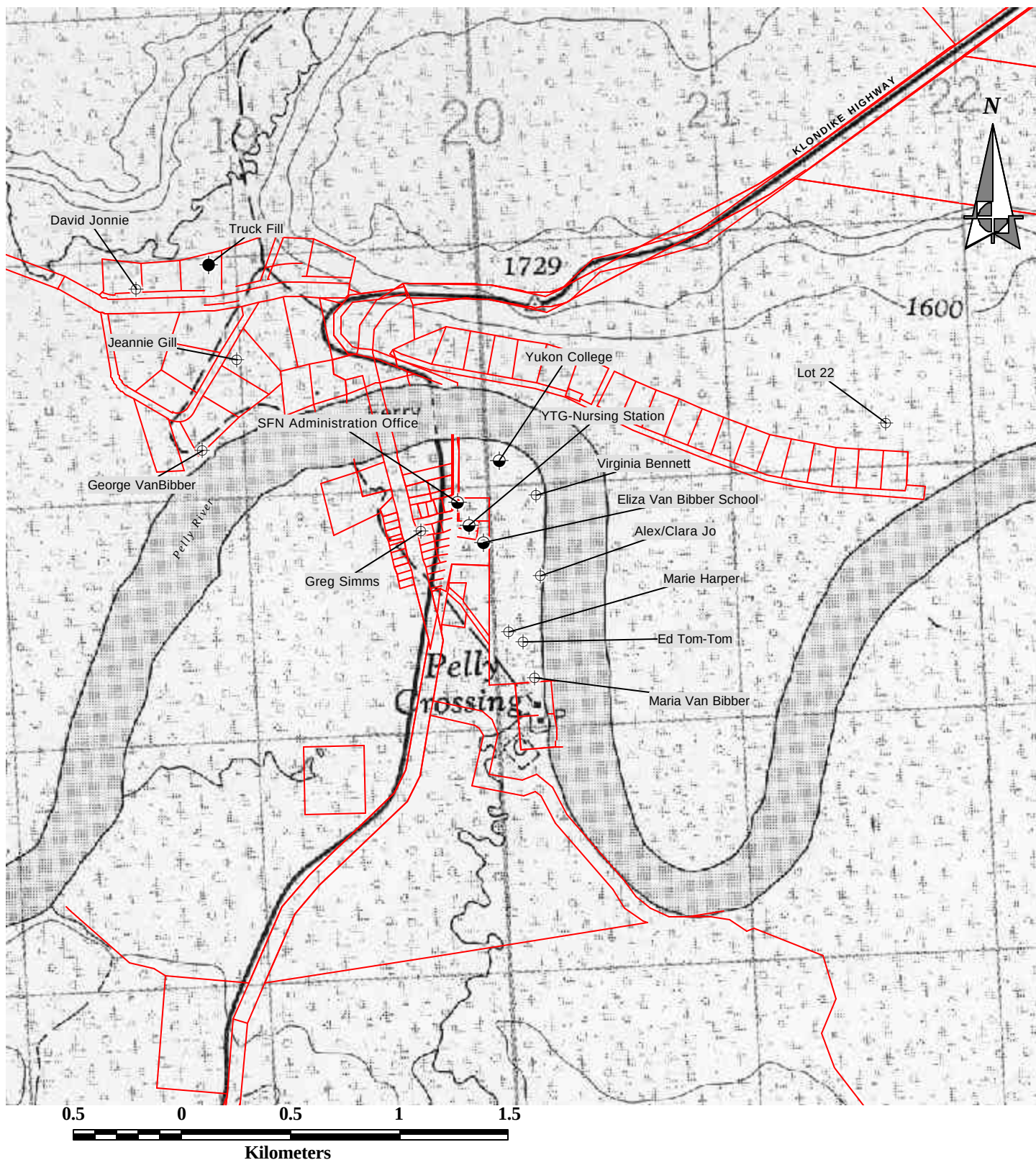
4.12.2 Pelly Crossing Climate

Climate normal data for Pelly Crossing for the period of 1996 to 2001 are summarized in Table 4.12-1.

Table 4.12-1 Climate Normals for Pelly Crossing, 1996-2001

Month	5-Year Mean Temperatures - Pelly Crossing (Degrees Celsius)			5 - Year Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-19.8	-30.52	-25.18	18.12
February	-10.24	-22.62	-16.46	10.84
March	-1.88	-18.96	-10.02	8.92
April	8.36	-5.76	1.3	10.48
May	15.04	0.7	7.88	30.54
June	21.9	7.24	14.6	49.54
July	22.76	8.92	15.86	64.28
August	20.02	6.1	34.7	45.92
September	12.96	1.26	7.12	40.52
October	1.54	-7.38	-2.96	23.62
November	-9.5	-16.5	-13	24.44
December	-15.84	-25.8	-20.84	19.8
Year	3.78	-8.61	-0.58	347.02

Source: Environment Canada.



Scale: 1:25,000

LEGEND:

Identified Water Well Locations
(number of wells)

- ⊕ Commercial/Institutional (4)
- ⊕ Domestic (10)
- Municipal/Communal (1)

Source of Drawing:
Energy, Mines and Resources Canada,
1961. National Topographic Series 115/15

Reviewed By: FKP

Drawn By: GC

Revised: October, 2003

Project Number: 22-680

File Name: 2268_PELX_fig1_Final.WOR

Revision: 0

**Pelly Crossing
Known Well Locations**

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Lee

Figure No. **4.12-1**

4.12.3 Pelly Crossing Topography and Hydrology

Pelly Crossing is developed on the Pelly River flood plain within a meander of the Pelly River. Land within and near the community slopes and drains gently to the west. Across the Pelly River to the north, topography rises steeply from the river valley and surface water runoff in general flows south, toward the Pelly River.

4.12.4 Pelly Crossing Geology

The terrain map of the Pelly Crossing area that was prepared for this project is found in Figure 4.12-2. The community is located on both sides of the Pelly River valley. The community core is located on a sand and gravel fluvial plain of the Pelly River. On the north side of the river, residential areas are located on a series of glaciofluvial terraces. It is interpreted that most of the community is underlain by primarily sand and gravel. Soil is reported to be relatively free of permafrost. The most recent surficial geology map of the is that of Jackson (1997). Neither depth to bedrock beneath the community nor bedrock type underlying the community are identified in the reviewed materials.

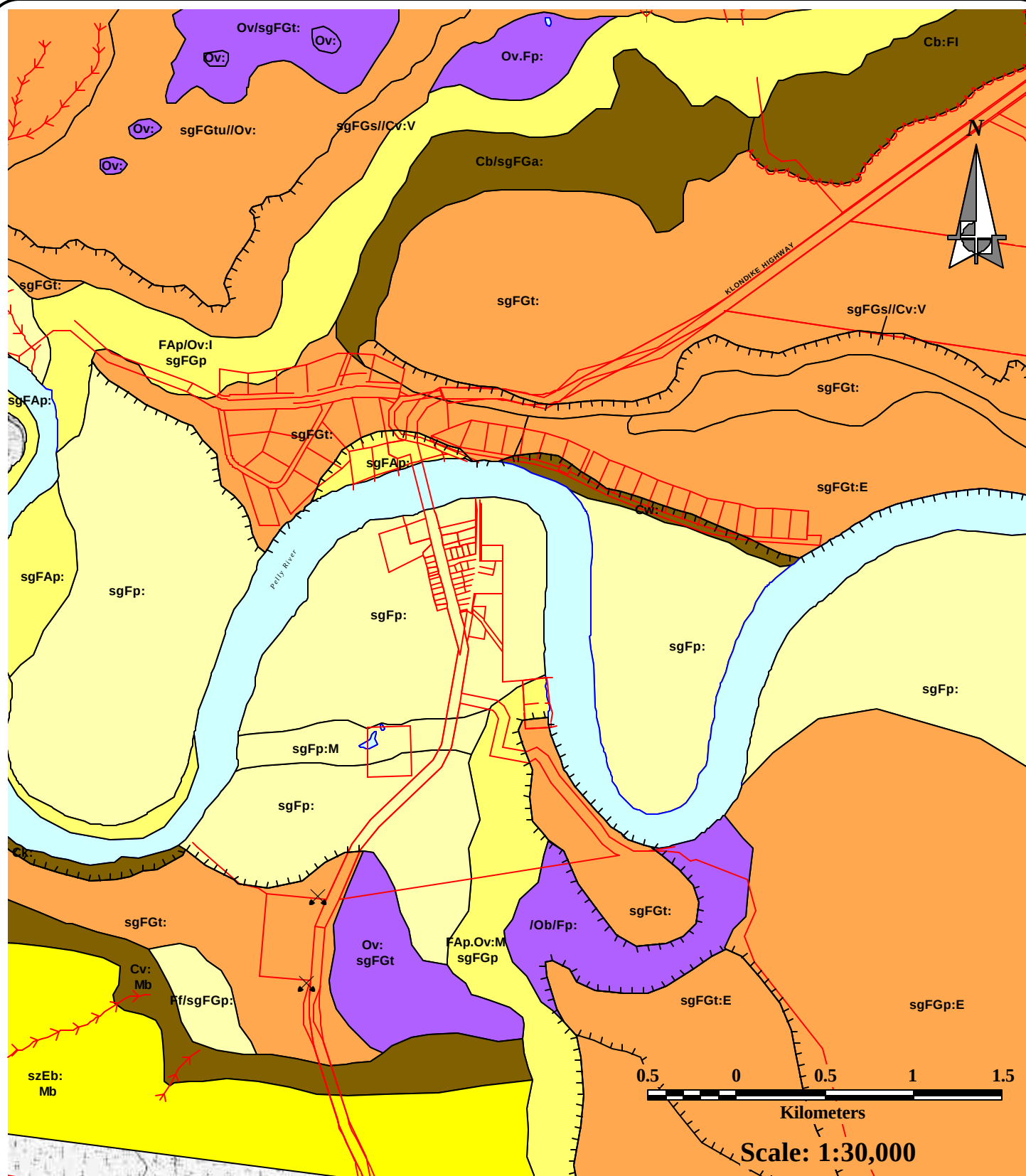
4.12.5 Pelly Crossing Hydrogeology

Locations of identified water wells in Pelly Crossing are shown on Figure 4.12-1. Most wells are shallow dug and drilled wells that are completed in one ore a series of shallow, unconfined aquifer(s). The aquifer(s) are likely hydraulically connected to the Pelly River. Reported depths to the saturated part of the aquifer(s) generally range between approximately 6 m and 11 m. Unconsolidated alluvial sediments lie beneath the Pelly River. There is a potential for additional deep confined aquifers to exist within these alluvial sediments beneath Pelly Crossing.

4.12.6 Pelly Crossing Community Visit

Gartner Lee visited Pelly Crossing on December 9, 2002. During the visit, Messrs. Alex Bath and Gavin Cook of Gartner Lee visited the following individuals and locations:

- Mr. Greg Simms, Capital Projects Director for SFN. Mr. Simms provided access to nine residences, the Pelly Crossing Campus of Yukon College and the SFN Administration Building. The most common water concerns that were identified by residents were with black and orange stains on water fixtures or appliances and strong sulfur-like odors. Most residents do not drink groundwater from their wells due to fear of bacterial contamination from septic systems. Most residents drink bottled water.
- Eliza Van Bibber School. No water concerns were identified.



LEGEND:	C - Colluvium	Gravel Pit	Extent of terrain analysis
E - Eolian	Gully		
F - Fluvial	Escarpment		
FA - Fluvial, active			
FG - Glaciofluvial			
M - Morainal (till)			
O - Organic			

Note: See Figure 2.2-1 for the Terrain Interpretation Legend

Source of Basemap:
Energy, Mines and Resources Canada,
1961, National Topographic Series 115/15
Reviewed By: FKP
Drawn By: NS/FKP
Revised: July 2003
Project Number: 22-680
File Name: 2268_PELX_fig2.WOR
Revision: 0

Pelly Crossing Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Gartner Lee

Figure No.

4.12-2

Yukon Groundwater and Ground Source Heat Potential Inventory

Pelly Crossing Nursing Station. Groundwater is obtained from a recently drilled well. The new well is deeper than the original well and was installed due to fear of septic contamination of shallow groundwater. The water from the new well is reported to be of poorer (aesthetic) quality than groundwater from the original well and an extensive water treatment system was installed to improve water aesthetics.

- Truck Fill well. No concerns were identified. Groundwater from this well is chlorinated prior to being distributed throughout the community using a truck

The results of groundwater field measurements by Gartner Lee on December 9, 2002 are summarized in Table 4.12-2.

Table 4.12-2 Pelly Crossing Groundwater Field Variables Measured on December 9, 2002

Location	Temp (Degrees C)	pH	Electrical Conductivity ($\mu\text{S}/\text{cm}$)	Field Hardness	Comments
Pelly Crossing Campus, Yukon College	4.6	7.5	350	Hard	Clear, odorless, no reported concerns
Virginia Bennett well	7.4	7.5	357	Hard	Clear, odorless, no reported concerns
Alex and Clara Jo well	6.6	7.2	456	Hard	Clear, odorless, no reported concerns
Maria Van Bibber well	4.8	7.2	375	Hard	Orange and black staining, sulfur-like odor
Ed Tom-Tom well	7.1	7.3	370	Hard	Orange staining, metallic odor, weak sulfur-like odor, not used for drinking
Marie Harper well	7.4	7.4	362	Hard	Orange staining, weak sulfur-like odor
SFN Administration Building well	3.5	7.3	597	Hard	Clear, odorless, no concerns reported
Greg Simms well	5.3	7.2	423	Hard	Clear, odorless, no concerns reported
Willow Creek Community (truck Fill) well	4.2	7.0	336	Hard	Clear, odorless, no concerns reported
David Jonnie well	8.5	7.3	373	Hard	Strong Sulfur-like odor, fluctuating temperature during purging: pump off 8.5, pump on 9.5
George Van Bibber well	5.8	7.1	360	Hard	Sulfur-like odor, orange staining
Jeannie Gill well	6.7	7.0	328	Hard	Clear, odorless, no concerns reported
Eliza Van Bibber School well	5.6	7.4	383	Hard	Clear, odorless, no concerns reported
Nursing Station well	7.3	7.3	388	Hard	Deposits a film, orange staining, water is filtered and stored in a tank prior to use

4.12.7 Pelly Crossing Water Supply

In 1975, Pelly Crossing was not equipped with a municipal water-distribution system. Each residence and building was either equipped with a private well or residents and users obtained water from the Pelly River. In 1988, approximately 40 per cent of town buildings were equipped with private wells that were completed within the shallow sand and gravel aquifer(s).

The reviewed materials report that in September 1988, Midnight Sun Drilling Company Ltd. installed at least 18 private wells in Pelly Crossing for SFN. The wells were completed between depths of 12.2 m and 14.0 m in one or more sand and gravel aquifers. At the time of installation, Midnight Sun Drilling estimated yields from private wells at between 0.3 L/sec and 0.9 L/sec.

In 1991, the Pelly Crossing restaurant/motel/service station, nursing station, school, RCMP detachment, community washhouse, SFN Administration Building and the skating rink were each equipped with a private well. Each well is completed in gravel at a depth of approximately 20 m. At this time, some residents were not equipped with a private well and continued to obtain water from nearby wells (YTG 1991).

In 2001, a private well was installed at a campsite located west of the Klondike Highway. The well was completed in gravel at a depth of approximately 8.2 m. When installed, the well had an estimated yield of approximately 113 L/min. Also in 2001, a private well was installed at a duplex residence near the SFN Administration Building. The well was completed at a depth of approximately 10.7 m in gravel and, when installed, had an estimated yield of approximately 1.1 L/s. In 2002, 49 houses were located in the main SFN village and each was equipped with a private well.

The Willow Creek subdivision community (truck fill) well is located north of the Pelly River on a raised alluvial terrace. The well is completed at a depth of 41.7 m, reportedly within an unconfined aquifer. The well is reported to be capable of yielding 4.6 L/s of water. In August 1996, the depth to static water in the well was approximately 18.48 m below the ground surface. The results of aquifer testing that was undertaken in August 1996 reported that the transmissivity of this aquifer is 3,380 m²/day and the long-term yield of the well is estimated to exceed 400 m³/day (4.6 L/s). The Willow Creek subdivision water-supply system was constructed in 1996 and in 2003 includes a treatment (chlorination) plant and two reservoirs. Water from the well is distributed using a truck throughout the subdivision and to residents in the nearby Jon/Ra subdivision.

David Nairne & Associates Ltd. (1995) reported on a well within the Willow Creek subdivision at an unspecified location. This well is 26.8 m deep and the sand and gravel aquifer in which the well is completed is located between depths of 20.7 m and 26.8 m beneath 10.6 m of sandy and clayey silt and "till". The presence of the silty and clayey soil and "till" above the aquifer suggests that the aquifer in which the well is completed is confined. In 1995, the depth to static water in the well was 18.6 m. Based

on pumping tests that were undertaken in 1995, the sustainable yield of the well was estimated by others to be at least 370 L/min. The results of monitoring and laboratory analyses of groundwater that was collected during the 1995 pumping test indicate that when tested, the temperature of the groundwater was 3.7 degrees Celsius, the iron content of the groundwater was less than 0.3 mg/L, the groundwater pH was between 6.5 and 7.5 and the total hardness of the groundwater was 136.8 mg/L.

Several private wells are reported to have been installed within the Jon/Ra subdivision north of the Pelly River. Groundwater from the wells is reported to be of poor (aesthetic) quality and many of the subdivision residents use water from the Willow Creek community well for drinking.

4.12.8 Pelly Crossing Groundwater Quality

Selected groundwater quality information that may be relevant to the operation of GSHP systems is summarized in Table 4.12-3.

Table 4.12-3 Selected Characteristics of Pelly Crossing Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Teddy Charlie Unit No. 2 well (July 1994)	6.56	634	651			Lorimer (1995) in Gartner Lee (2002)
Charlie Joe Unit No. 6 well (July 1994)	7.66	207	213	1.65	0.254	Lorimer (1995) in Gartner Lee (2002)
Willow Creek subdivision community (truck fill) well (September 1996)	7.64	207	185	<0.05	0.0021	HCL (1996) in Gartner Lee (2000)
Willow Creek Subdivision community (truck fill) well (September 2001)	8.1	156	156	<0.03	<0.02	
Unspecified Jon/Ra Subdivision well (August 1997)	6.74	473	456	5.02	0.252	Gartner Lee (2002)
Unit 44 well (January 1999)	7.51	266	250	<0.03	<0.001	EBA (1977) in Gartner Lee (2002)
Unit 31 well (January 1999)	7.63	238	224	<0.03	0.011	EBA (1977) in Gartner Lee (2002)
Unit 27 well (January 1999)	7.76	183	169	0.12	0.061	EBA (1977) in Gartner Lee (2002)
Unit 32 well (January 1999)	7.71	187	178	<0.03	0.186	EBA (1977) in Gartner Lee (2002)
SFN Administration Office well (January 1999)	7.64	280	228	<0.03	<0.001	EBA (1977) in Gartner Lee (2002)

Yukon Groundwater and Ground Source Heat Potential Inventory

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Annie McGinity well (February 1996)	7.73	107	99.7	<0.03	0.014	Gartner Lee (2002)
Tommy Joe Unit 33 well	7.75	205	192	<0.03	0.014	EBA (1977) in Gartner Lee (2002)
Nursing Station well (October 1998)	8.08	202	184	0.12	0.313	Gartner Lee (2002)

According to information that is identified in the reviewed materials:

- The aesthetic quality of groundwater yielded by private wells in the Jon/Ra Subdivision (most of which were installed in approximately 1995) is reported to be poor.
- In 2002, identified concerns with the private wells in Pelly Crossing included the following: a) many well heads are below grade and susceptible to flooding; and b) most wells are located within 30 m of septic fields. Elevated concentrations of nitrate in groundwater have been identified beneath the community.
- According to Lorimer and Associates (1995), concentrations of nitrate in groundwater within the community are usually lower than the Canadian Drinking Water Quality Guideline of 10 mg/L. However, groundwater from seven community wells has contained nitrate concentrations above the 10 mg/L guideline. This is usually indicative of nitrate contamination. This problem is most likely caused by septic contamination.

4.12.9 Pelly Crossing GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	• High yield aquifers exist near surface • Groundwater temperatures appear to be relatively stable and somewhat warm • Poor water quality may require special consideration during design and operation of GWHP systems • Most residential private wells could be used for individual GWHP systems • GSHP system water disposal should be easy • Warmer groundwater may be found in unconsolidated sediments with depth, however quality may be worse
GCHP	Moderate to good	• Coarse grained saturated soils provide relatively good thermal conductivity • Good groundwater flow under community is anticipated

Development of groundwater resources appears to be relatively easy in Pelly Crossing. Furthermore, groundwater temperatures do not appear to become too cold in winter (due to cold surface water

interaction). Therefore, development of GWHP systems may be attractive for this community. *It is recommended that continuous temperature monitoring of groundwater from a major community building's well (e.g., the school well) be conducted to assess seasonal groundwater temperature fluctuations.* Based on this GWHP systems should be considered for heating of facilities and homes in the community.

Private water wells can also be used for heating of individual homes. However, care should be taken to prevent fouling of the heat pump equipment. *It is recommended that an example home with a private well be selected to demonstrate the viability of the technology to the community.*

4.13 Ross River

4.13.1 Ross River Community Description

Ross River is near the south shore of the Pelly River approximately 1.2 km west of its confluence with the Ross River. The community is located between mountains of the Anvil Range (to the north) and St. Cyr Range (to the south) and is approximately 360 km northeast of Whitehorse. A location map that shows Ross River and the surrounding topography is shown in Figure 4.13–1. A community profile of Ross River appears in Appendix A.

Ross River is located within the traditional hunting and trapping area of the Kaska Dena people (also referred to as the Ross River Dena Council). The population of the community is 329 (Yukon Bureau of Statistics 2003). Electricity for Ross River is supplied by Yukon Energy Corporation from its Whitehorse-Aishihik-Faro power grid and from an emergency diesel generator plant that is located within the community.

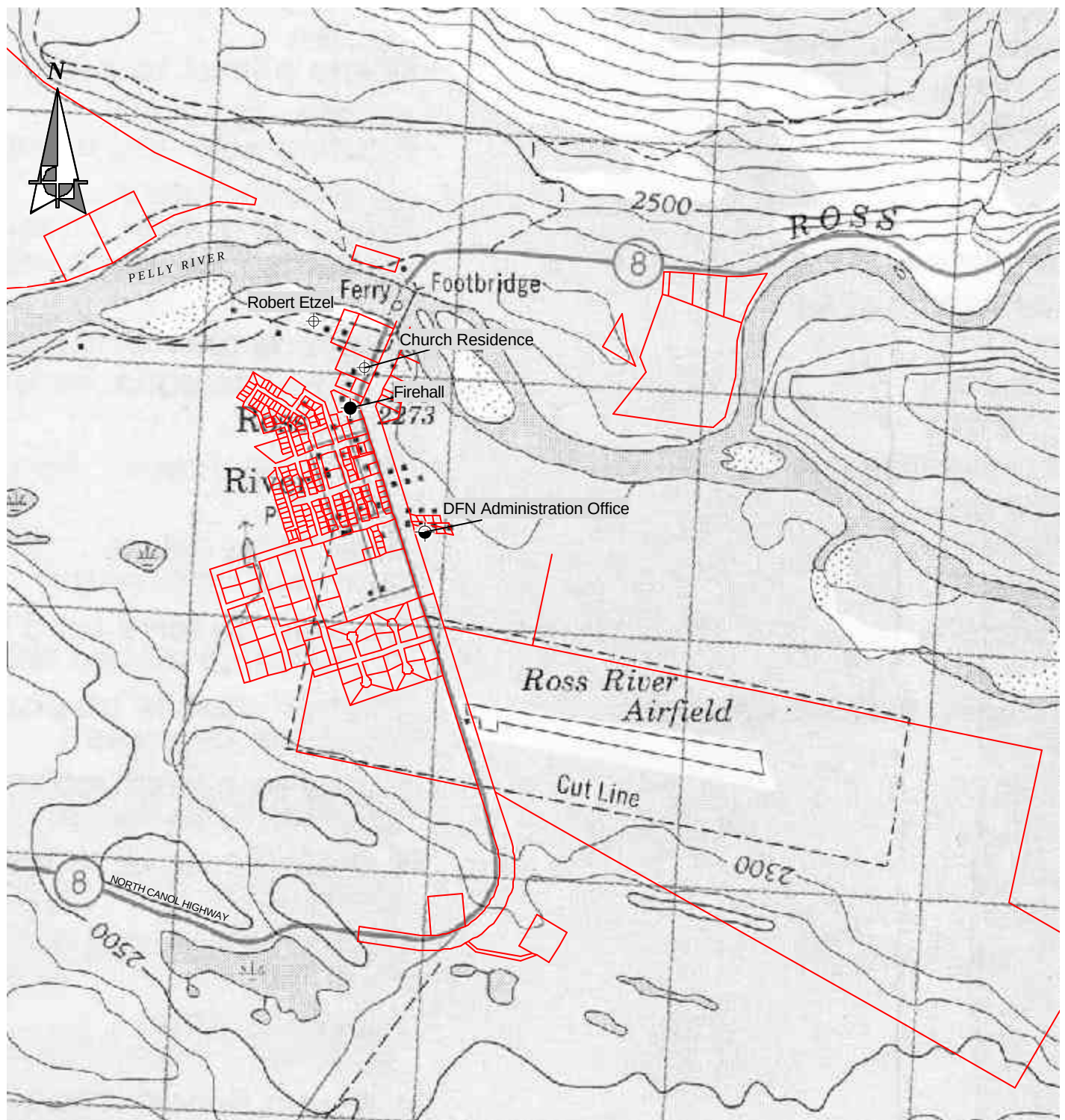
4.13.2 Ross River Climate

Climate normal data for Ross River for the period between 1996 to 2001 appear in Table 4.13-1.

Table 4.13-1 Climate Normals for Ross River, 1996 - 2001

Month	5-Year Mean Temperatures - Ross River (Degrees Celsius)			5 - Year Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-16.54	-31.88	-23.08	9.38
February	-6.97	-24.67	-16.33	9.83
March	-1.40	-21.48	-11.02	0.30
April	7.43	-8.20	1.98	5.50
May	13.95	-1.63	6.35	23.25
June	21.18	5.08	13.00	26.62
July	22.14	6.06	13.96	30.36
August	19.65	2.93	11.30	36.63
September	12.80	-1.85	5.00	24.25
October	2.73	-7.87	-2.10	17.50
November	-10.50	-18.93	-14.57	15.83
December	-14.84	-27.16	-20.40	7.75
Year	4.14	-10.80	-2.99	207.20

Source: Environment Canada.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND: Identified Water Well Locations
(number of wells)

- ⊕ Commercial/Institutional (1)
- ⊕ Domestic (2)
- Municipal/Communal (1)

Source of Drawing:
Energy, Mines and Resources Canada,
1974, National Topographic Series 105E/16
Reviewed By: FKP
Drawn By: GC
Date Revised: October, 2003
Project Number: 22-680
File Name: 22680_Ross_fig1_Final.WOR
Revision: 0

**Ross River
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.13-1**

4.13.3 Ross River Topography and Hydrology

The elevation of Ross River is approximately 693 m amsl. The community is developed on a raised alluvial terrace near the south shore of the Pelly River. Surface water runoff originating within the community will, in general, flow toward the Pelly River. Indian and Northern Affairs Canada estimated the 100 year flood elevation of the Pelly River at Ross River to be 694.0 m (at a discharge rate of 2,100 m³/sec).

Permafrost conditions are developed beneath the town at depths of between 0.7 m and 9 m. In 1989, Hoggan Engineering observed permanently frozen soil at 36 test hole locations within and near Ross River at depths of between 1.2 m and 8.7 m. The average depth at which frozen soil was encountered in the 36 test holes was 4.6 m. Permafrost is widespread within and near Ross River at depths exceeding 3.5 m. When the community water well was installed in September 1986, permafrost was encountered in the well's borehole between depths of 8.2 m and 18.6 m. Intera (1975) reported that permafrost was encountered between depths of 3.3 m and 24 m at the location of the school well.

4.13.4 Ross River Geology

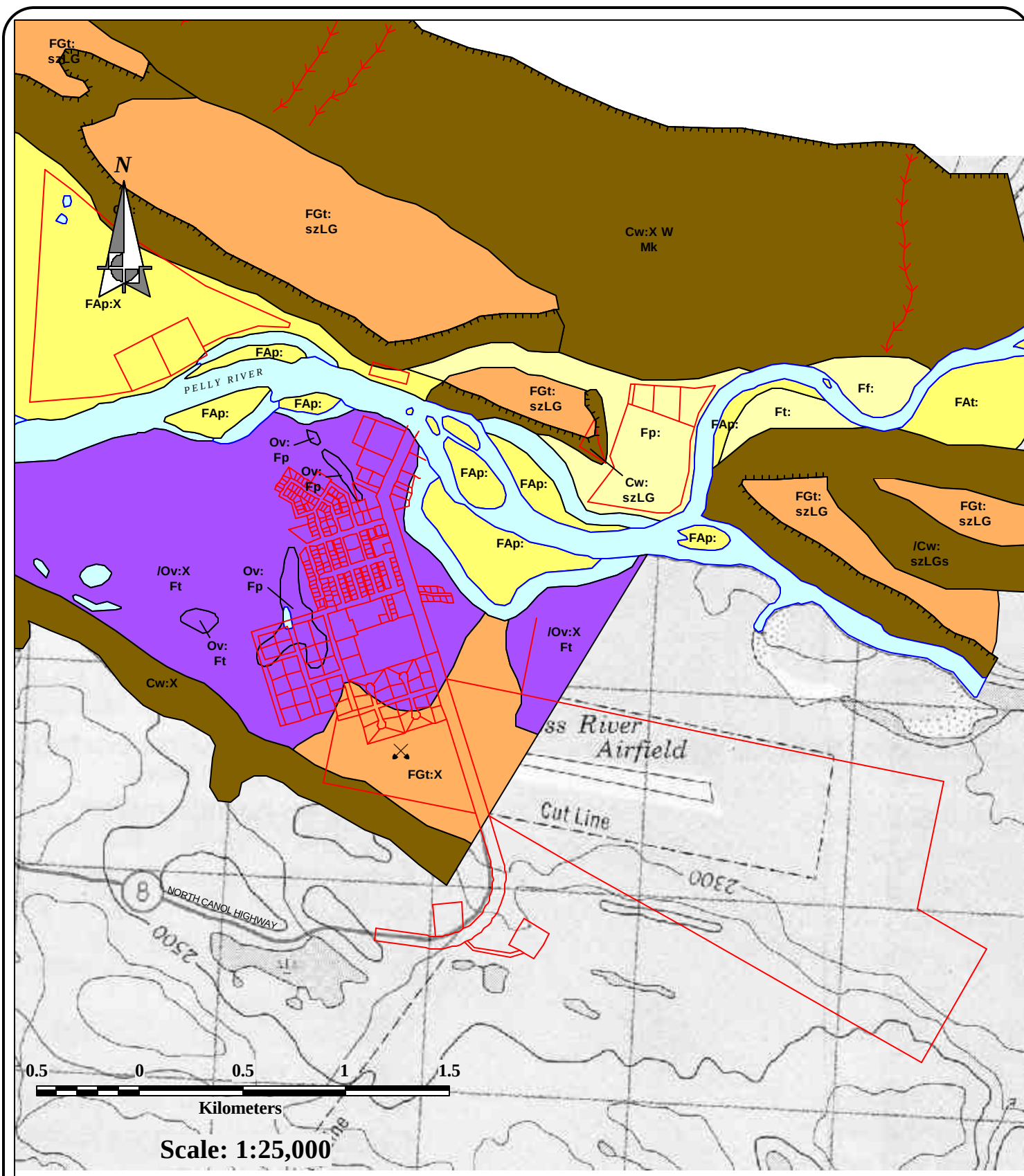
A terrain map for the Ross River area is found in Figure 4.13-2.

The town is situated on an alluvial terrace that is adjacent to the Pelly River. Intera (1975) indicated that the terrace is underlain mainly by gravel. The town is bounded by the active flood plain of the Pelly River to the north and the escarpment of the Pelly River Valley (located less than 1 km to the south). Soil consists mainly of a frozen organic veneer that is inferred to overlie deposits of river sand and gravel. These deposits extend to approximately 10 m below surface and overly lacustrine silt and clay. The lacustrine deposits are reported to extend to depths of more than 100 m (Intera 1975).

Bedrock is reported to be exposed on upland terraces that are south of town. These exposures are bedded claystone, siltstone, shale, coal; sandstone and pebble to boulder conglomerate. Bedrock underlying the community has been encountered at a depth of approximately 150 m (Intera 1975). The results of regional scale bedrock mapping show that bedrock underlying the community consists mainly of quartzite, quartz muscovite schist and minor metaconglomerate (Gordey and Makepeace 2000).

4.13.5 Ross River Hydrogeology

Locations of identified water wells in Ross River appear on Figure 4.13-1. Most identified wells are completed in shallow sands and gravels. The shallow aquifer or aquifers in which the wells are completed are likely to be hydraulically connected to the Pelly River.



LEGEND:

Primary Surficial Material

- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- FG - Glaciofluvial
- O - Organic

- Gravel Pit
- Escarpment
- Gully

- Extent of Terrain Analysis

Note: See Figure 2.2-1 for the terrain interpretation legend

Source of Drawing:
Energy, Mines and Resources Canada,
1974. National Topographic Series 105E/16
Reviewed By: FKP
Drawn By: NS/FKP
Date Revised: July 2003
Project Number: 22-680
File Name: 22680_Ross_fig2.WOR
Revision: 0

Ross River Terrain Interpretation

Yukon Groundwater and Ground Heat
Potential Inventory



Figure No. **4.13-2**

The depth to the water table beneath Ross River is reported to be, typically, between 1 m and 1.5 m. In 1989, Hoggan Engineering installed three groundwater monitoring well within and near Ross River. Measured depths to static water in shallow wells in 1995 ranged between 2.5 m and 3.2 m. Several wells in the community, including the municipal well, are completed within one or more deep confined aquifers.

Information in Access (2002) indicates that historically, analyzed groundwater from the community well has contained concentrations of arsenic and manganese that exceed the Canadian Drinking Water Quality Guidelines.

4.13.6 Ross River Community Visit

Gartner Lee visited Ross River on December 11, 2002. During this visit, Gartner Lee visited the following individuals and completed the following tasks:

- The driver of the water truck that delivers chlorinated water to residents of the community identified residences to which water is not delivered.
- At the Church Residence (occupied by Father Roberts at the time of the visit), no groundwater concerns were identified. The well at the Church residence is reported to have historically supplied water to the community.
- Mr. Jack Caesar, Chief of the Ross River Dena First Nation (DFN) provided access to the DFN Administration Office well. No concerns with the quality of water from the well were identified.

The results of groundwater field measurement by Gartner Lee during the community visit are summarized in Table 4.13-2.

Table 4.13-2 Ross River Groundwater Field Variables Measured on December 11, 2002

Location	Temp. (Degrees C)	pH	Electrical Conductivity (µmho/cm)	Field Hardness	Comments
Community (Firehall) Well	5.1	8.0	622	Very Hard	No water quality issues reported
Church (Father Roberts) Residence Well	4.8	7.3	860	Hard	No complaints reported, well used to service entire community
DFN Administration Office Well	8.9*	8.0	585	Hard	Orange staining, sulfur odor *water temp increased when pump was operating indicating that actual groundwater temperature may differ from that reported here

4.13.7 Ross River Municipal Water-Supply

Since at least 1978, most residents and users of Ross River have obtained their water from a truck that is filled with water from the town well (located within the firehall). Prior to 1978, municipal water was obtained from a municipal well that was located near the Pelly River.

The existing Ross River town well was installed in September 1986. The well is screened between depths of 105.1 m and 110.0 m within a gravel aquifer between depths of 101.5 m and 110.0 m. Low permeability silt and sand occurs between the community well aquifer and shallow aquifers that occur beneath the town.

The design yield of the community well is 18.9 L/sec. Maximum pumping rates achieved during development of the well were between 15 L/sec and 23 L/sec. Based on the results of pumping tests that were undertaken during October 1986, Stanley Associates estimated the transmissivity of the community well aquifer to be 2961 m²/day and the long-term yield of the well of up to 300L/s. Measured temperature and electrical conductivity of groundwater from the community well during the 1986 pumping tests were 5 degrees Celsius. The community well was commissioned in 1988.

Chlorinated water from the Ross River community well is temporarily stored in a reservoir that is located in the firehall. Daily average water-use rates for Ross River for years 1995 through 2001 ranged from 27 to 46 m³.

The DFN Administration Building and DFN Wash House received water from a well that is located in the wash house parking lot. The well was installed in 1989 and is completed at a depth of approximately 110 m. Water from this well is piped to the wash house, where it passes through a sand filter and a water softener after which it is distributed to both the wash house and the administration building.

A well at Ross River "forestry buildings" that was installed prior to 1975 was completed within a sand and gravel aquifer above a depth of approximately 9.7 m. The well's borehole was advanced to a depth of 147.5 m prior to installing the well. At this location, between depths of 9.7 m and 144.8 m, information on the well's borehole log that is summarized by Intera (1975) indicates that the soil consists of interbedded silt, silty gravel, "till", clay and gravel. Below a depth of 147.5 m, the borehole encountered broken rock.

In December 2002, four operating private wells were reported to be located within Ross River and within residentially developed areas north of the Pelly River as follows: a) the town (firehall) well, b) one well near the Ross River Church (the church residence well), c) the Don McKay private well and d) the Robert Etzel private well.

4.13.8 Quality of Ross River Groundwater

Selected groundwater quality information that may be relevant to the operation of GSHP systems in Ross River is summarized in Table 4.13-3.

Table 4.13-3 Characteristics of Ross River Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Community Well near Pelly River (December 1973)	7.7	262	212	0.22	-	Intera (1975)
Bill Carlson well (December 1973)	7.65	431	320	0.13	-	Intera (1975)
Community (firehall) Well (October 1986)	8.13	292	218	<0.10	0.07	Stanley Associates (1986)
Community (firehall) Well (July 1988)	8.1	277	220	0.240	0.074	Gartner Lee (2002)
Community (firehall) Well (June 1990)	8.6	287	245	0.044	0.074	Gartner Lee (2002)
Community (firehall) Well (March 1993)	8.49	301	221	0.105	0.079	Gartner Lee (2002)
Community (firehall) Well (September 1998)	8.17	301	214	0.08	0.078	Gartner Lee (2002)
Community (firehall) Well (November 1999)	8.15	301	214	0.06	0.082	Access Consulting (2002)
Community (firehall) Well (October 2000)	8.09	277	223	0.05	0.078	Access Consulting (2002)
Community (firehall) Well (June 2001)	7.6	287	196	0.349	0.0796	Gartner Lee (2002)
Community (firehall) Well (December 2001)	8.32	293	223	0.04	0.082	Access Consulting (2002)
Nursing Station (February 1997)	8.27	299	225	0.14	0.081	Gartner Lee (2002)
Robert Etzel Well (June 2001)	7.70	482	279	0.021	0.0041	Gartner Lee (2002)

4.13.9 Ross River GSHP Potential

GSHP Type	Potential	Comments
GWHP	High	• The community well is high yield and is under-utilized • Community groundwater has a temperature of 5 degrees Celsius • The community aquifer is deep (110 m) • Groundwater is hard and will require careful management for GSHP applications
GCHP	Low to Moderate	• Mainly fine grained saturated soil is present, permafrost occurs within 20 m of the ground surface • No bedrock near surface to limit borehole depths

The community well is reported to be of high yield and currently appears to be under utilized. Temperatures of groundwater from the well are relatively warm (5 degrees Celsius). *It is recommended that a feasibility study be completed for utilizing the community well aquifer or other deep aquifers for GWHP heating of community buildings.*

4.14 Town of Teslin

4.14.1 Teslin Community Description

Teslin is at Alaska Highway Kilometre 1,294 (Mile 804) near the north shore of Teslin Lake/Nisutlin Bay near the confluence of the Nisutlin River with Teslin Lake. Teslin is approximately 183 km east of Whitehorse and approximately 260 km west of Watson Lake. Historically, Teslin Lake was an important First Nation fishery. Following construction of the Alaska Highway in 1942, Teslin became a permanent settlement. The current population of the community is 396 (Yukon Bureau of Statistics 2003) A location map that shows Teslin and surrounding topography appears as Figure 4.14-1. A community profile of Teslin is appears in Appendix A.

Teslin is within the traditional hunting and trapping area of the Tlingit people and the town is home to members of the Teslin Tlingit First Nation (TTFN). Electricity is supplied to Teslin by Yukon Energy Corporation from the Whitehorse-Aishihik-Faro grid with on-site emergency diesel generators.

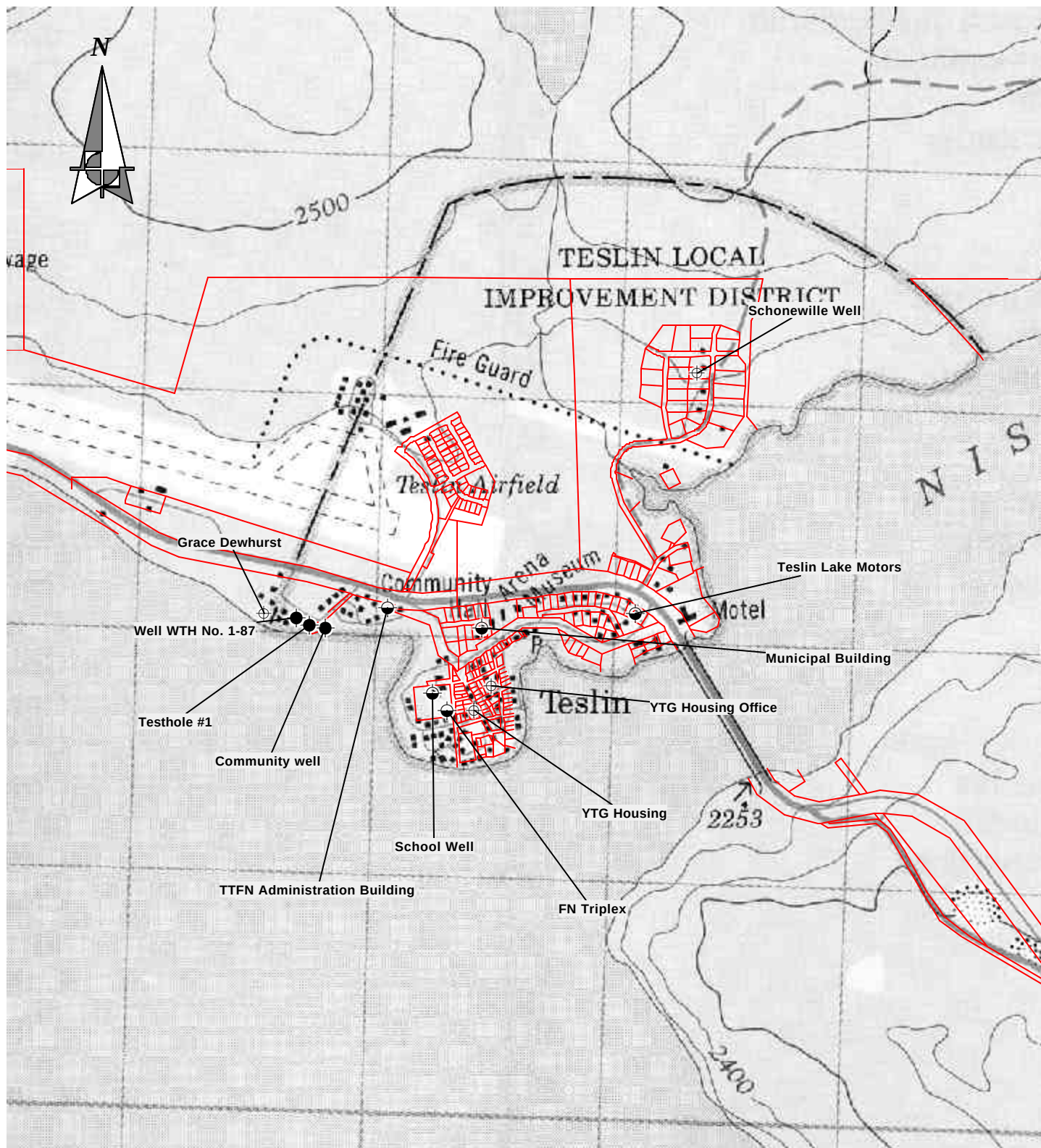
4.14.2 Teslin Climate

Climate normal data for Teslin for the period of 1996 to 2001 are provided in Table 4.14-1.

Table 4.14-1 Climate Normals for Teslin, 1996 - 2001

Month	5-Year Mean Temperatures - Teslin (Degrees Celsius)			5 – Year Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-12.4	-22.03	-17.18	23.73
February	-5.5	-17.90	-11.73	7.73
March	-0.7	-12.90	-6.68	14.28
April	7.0	-5.38	0.82	9.40
May	13.6	1.05	6.20	15.33
June	19.5	5.44	12.52	28.52
July	20.4	7.62	14.00	45.98
August	19.1	5.70	12.43	44.72
September	12.9	3.83	7.58	48.63
October	4.5	-3.30	0.60	36.44
November	-4.3	-11.56	-7.90	19.30
December	-8.3	-16.96	-14.68	23.24
Year	5.5	-5.53	-0.34	317.28

Source: Environment Canada 2002.



0.5 0 0.5 1 1.5
Kilometers

Scale: 1:25,000

LEGEND:

**Identified Water Well Locations
(number of wells)**

- ⊙ Commercial/Institutional (5)
- ⊕ Domestic (4)
- Municipal/Communal (3)

Source of Drawing:
Energy, Mines and Resources Canada,
1984 National Topographic Series 105 C/02
Reviewed By: FKP
Drawn By: GC
Revised: October, 2003
Project Number: 22-680
File Name: 22680_TSLN_fig1_Final.WOR
Revision: 0

**Teslin
Known Well Locations**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Figure No. **4.14-1**

4.14.3 Teslin Topography and Hydrology

Teslin is within the Yukon Plateau physiographic division of the Canadian Cordillera. The town is near the northeast shore of Teslin Lake, which is part of the Yukon River drainage system. In general, the ground surface within and near Teslin slopes and drains toward Teslin Lake. Historically, the elevation of Teslin Lake is reported to have fluctuated seasonally by as much as 9 m. In general, the town is described to be permafrost-free.

4.14.4 Teslin Geology

A terrain map of the Teslin area is presented as Figure 4.14-2. The town is located on a rolling plain of glacial till. Gravelly beach deposits occur along the lake margin. Some small wetlands are covered by an organic-rich veneer. Depth to bedrock under the community is greater than 90 m below surface. Bedrock is not exposed in the community, but is described by Gordey and Makepeace (2000) as greywacke and lesser siltstone and shale of the Shonektaw Formation.

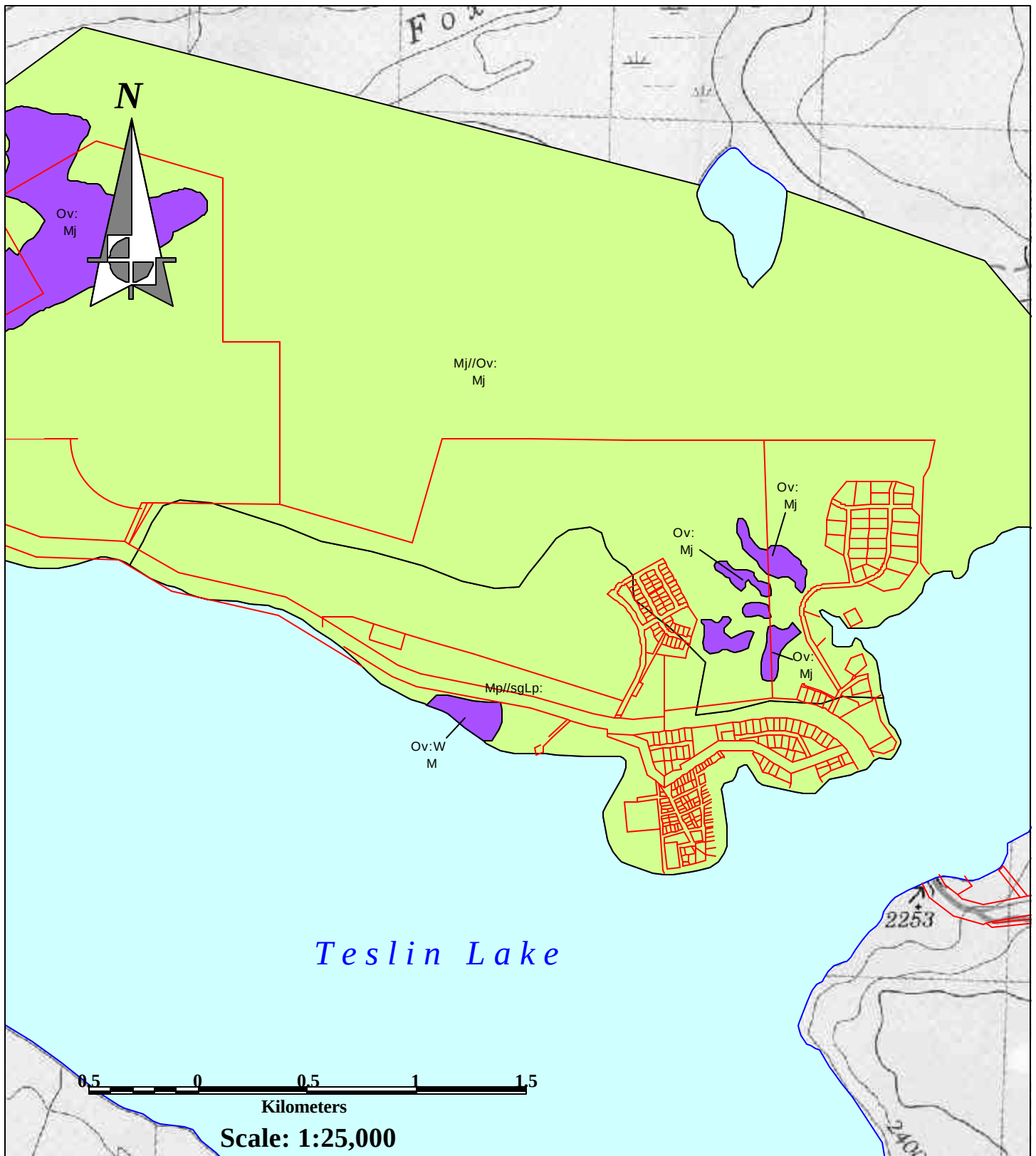
4.14.5 Teslin Hydrogeology

Locations of identified water wells in Teslin are shown on Figure 4.14-2. Most identified wells are completed in unconfined shallow sand and gravel aquifers.

4.14.6 Teslin Community Visit

Gartner Lee visited Teslin on December 13, 2002. During the visit, Messrs. Alex Bath and Gavin Cook of Gartner Lee visited the following:

- Mr. Robert Gerald of the Teslin Public Works Department. Mr. Gerald provided temperature information for groundwater in the Teslin municipal well.
- Collection of groundwater field measurements in the Teslin Administration Building well. Users of the water reported that the water is of poor aesthetic quality. When visited by Gartner Lee, the water appeared cloudy, it emitted a strong mineral odor.
- Collection of groundwater field measurements at the Government of Yukon (YTG) Housing Office and the Triplex building. Groundwater at the Triplex is softened and filtered prior to being distributed. Orange staining was observed on plumbing fixtures.
- Mr. Vern Davies of TTFN. Mr. Lee provided access to the TTFN Administration Building and three TTFN residences and facilitated monitoring of groundwater field variables at these locations.



LEGEND:

Primary Surficial Material

- M - Morainal (till)
- O - Organic
- Extent of Terrian Analysis

Note: See figure 2.2-1 for the
Terrain Interpretation Legend

Source of Basemap:
Energy, Mines and Resources Canada,
1984 - National Topographic Series 105 C/02
Reviewed By: FKP
Drawn By: NS/FKP
Revised: July 2003
Project Number: 22-680
File Name: 22680_TSLN_fig2.WOR
Revision: 0

**Teslin
Terrain Interpretation**

**Yukon Groundwater and Ground Heat
Potential Inventory**



Gartner Lee

Figure No.

4.14-2

1. Water at the TTFN Administration building was reported to be of acceptable quality.
 2. Groundwater from the YTG Lot 6 well is softened and is odorous.
 3. Groundwater from the Lot 154 well tended to freeze. Ms. Bernice Shoheville complained of “blue to grey” sediment each spring.
- The results of groundwater field measurements by Gartner Lee on December 13, 2002 are summarized in Table 4.14-2.

Table 4.14-2 Teslin Groundwater Field Variables Measured on December 13, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µS/cm)	Field Hardness	Comments
TTFN Administration Building	7.5	7.7	1336	Soft	Cloudy, strong mineral odor,
YTG Housing	6.2	7.9	2216	Very Hard	Scaling issues reported, treatment system installed
YTG Housing Office	5.8	8.4	543	Hard	Treated Water was tested
Teslin Community Well (well WTN No. 1-87)	2.3*	Not able to sample well, temperature reported by Robert Gerald			

4.14.7 Teslin Water-Supply

Residents of Teslin obtain water from both a community well and private wells. Locations of identified wells in Teslin are shown on Figure 4.14-1.

Prior to 1980, most residents of Teslin obtained water from a truck that was filled at a reservoir near the Teslin airstrip. The principal source of the delivered water at this time was Teslin Lake. The water was obtained from the lake in part using an "on-shore" well. Both the lake-water "intake" and the pump house were constructed in approximately 1945.

In 1980, community well No. 1 was completed approximately 77 m north of and 20 m northeast of the historic pump house that had been used to obtain water from Teslin Lake. The well was completed within an inferred confined 12.5 m thick sand and gravel aquifer between depths of 15.8 m and 28.3 m.

In May 1980, Stanley Associates completed pumping tests using community well No. 1. Based on the results of the tests, Stanley Associates estimated that: the transmissivity of the community aquifer is at least 1,300 m²/day. The estimated sustainable yield for this well 1,075 m³/day (12 L/s).

In February 1987, Hydrogeological Consultants Ltd. undertook additional aquifer and well tests using community well No. 1, which was not yet in service. These test results are reported to indicate that the transmissivity of the community aquifer was 1,000 m²/day. The specific capacity of community well

No. 1 after ten minutes of pumping at a rate of 268 L/min was estimated to be 0.9 L/s per meter of drawdown.

In February 1987, Hydrogeological Consultants Ltd. advanced a test hole between community well No. 1 and Teslin Lake. The test hole was abandoned at a depth of 48.8 m for reasons that are not identified in the reviewed materials. HCL advanced a second test hole (WTH No. 1-87) approximately 23 m east of the first test hole to a depth of 121.9 m and installed a well in the borehole (well WTH No. 1-87). This well is screened between depths of 82.0 m and 84.4 m within the deepest of three sand and gravel aquifers that were identified. The depths of the aquifers are between 23.8 m and 28.6 m, between 29.0 m and 38.7 m and between 82.0 m and 90.8 m. HCL indicated that community well No 1 is completed within the shallowest of the three aquifers that were identified at WTH No. 1-87.

Hydrogeological Consultants Ltd. estimated that the transmissivity of the (deep) well WTH No. 1-87 aquifer is 170 m²/day. The reported specific capacity for the well after 10 minutes of pumping at a rate of 11.7L/s was 4.5 L/s per meter of drawdown. Following the 1997 pumping test, the temperature of groundwater from well WTH No. 1-87 was 4 degrees Celsius.

By 1991, the main source of water that was delivered to residents of Teslin using a truck appears to have been well WTH No. 1-87. At this time, the community water-supply system included a pump house (constructed in approximately 1990) and a 100,000 L reservoir. In 1991, the Teslin community water was described to be "very hard".

In 2002, most Teslin residents and residents of the TTFN Airport Subdivision, Smarchville and the main TTFN Village received treated water from well WTH No. 1-87 that was delivered using a truck. At this time, approximately half of individuals who received trucked water supplemented drank water from Teslin Lake or Ten Mile Creek rather than the well water.

Additional wells in Teslin include the following:

- One well at the Teslin School (installed in 1969). The well is completed between depths of 43.7 m and 45.3 m in a sand aquifer that is underlain by clay. The borehole in which the well is installed encountered sandy clay between depths of 1.3 m and 7.6 m, suggesting that the well is completed in a confined aquifer.
- One 54.8 m deep well at the "New Teslin School" (installed prior to 1974 by Midnight Sun Drilling Company Ltd.).
- The Teslin Lake Motors well (installed during or before 1975 and completed at a depth of 115.8 m). In 1975, the well is reported to have had a potential long-term yield of approximately 2.3 L/sec.
- Private wells are reported to have been installed at the following locations before 1975: the RCMP detachment, the Forestry Station residence (completed at a depth of 52 m near Teslin Lake), the rectory and the Nisutlin Bridge Lodge (9.7 m deep). These wells are completed above a depth of

approximately 34 m. Water levels in most wells fluctuate with the level of water in Teslin Lake, suggesting that the wells were (or are) hydraulically connected with the lake.

In 2002, 33 houses and community buildings in Teslin were equipped with 31 private wells. The locations of these wells are not identified in the reviewed materials. Most residents continued to receive treated water originating from well WTH No. 1-87 from a water truck. Most residents of the TTFN Airport Subdivision, Smarchville and Main Village also received trucked water from the Teslin reservoir. Based on several deep boreholes that are reported to have been drilled within Teslin and that failed to encounter aquifers, the distribution of potable groundwater from depths exceeding approximately 50 m is reported to be spotty. The locations of the dry deep boreholes are not identified in the reviewed materials.

4.14.8 Teslin Groundwater Quality

Selected groundwater quality information that may be relevant to the operation of GSHP systems in Teslin is summarized in Table 4.14-3.

Table 4.14-3 Selected Characteristics of Teslin Groundwater

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Teslin community "well" (December 1973)	8.2	226	122	0.4	<0.1	Intera (1975)
Teslin Well No. 1 (1980)*	7.5	420	367	0.76	0.52	Stanley Associates (1980)
WTH No. 1-87 (February 1987; groundwater from a depth of 31.7 m)	8.28	487	390	0.88	0.389	Hydrogeological Consultants (1987)
WTH No. 1-87 (February 1987; groundwater from a depth of 84.4 m)	8.07	257	222	0.25	0.033	Hydrogeological Consultants (1987)
WTH No. 1-87 (February 1987)**	7.8	259	210	0.107	0.036	Hydrogeological Consultants (1987)
Teslin Well No. 1 (February 1987)***	7.5	483	395	0.923	0.626	Hydrogeological Consultants (1987)
Forestry Service Residence Well (December 1972)	8.2	226	222	0.4	<0.1	Intera (1975)
Teslin School Well (September 1973)	8.01	315	264	0.13	-	Intera (1975), HGC (1974)
Teslin Lake Motors Well (December 1973)	7.85	147	172	0.06	-	Intera (1975), Hydrogeological Consultants (1974)
Ryans Dug Well (December 1973)	7.45	548	453	0.03	-	Hydrogeological Consultants (1974)

Yukon Groundwater and Ground Source Heat Potential Inventory

Well	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Liz Martinchuck Well (December 1973)	8.0	436	300	0.07		Hydrogeological Consultants (1974)
Teslin Lake (December 1973)	7.7	382	308	0.09		Hydrogeological Consultants (1974)
Teslin Lake Motors Well (February 1987?)		149	191	0.32	0.056	Hydrogeological Consultants (1987)
Ben Schonewille Well (February 1987?)+		107	194	0.24	0.017	Hydrogeological Consultants (1987)
Grace Dewhurst Well (October 1996)	8.22	315	223	0.49	0.214	Gartner Lee (2002)
TFN Administration Building Well (September 2001)	8.19	483	427	3.43	0.35	Gartner Lee (2002)

* Groundwater temperature was 2.2 degrees Celsius.

** Groundwater temperature was 4.0 degrees Celsius.

*** Groundwater temperature was 3.0 degrees Celsius.

+ the Ben Schonewille well is completed at a depth of 121.9 m.

4.14.9 Teslin GSHP Potential

GSHP Type	Potential	Comments
GWHP	Moderate	- Community well is high yield - Groundwater temperatures may be too cold for GWHP applications - Groundwater is hard with elevated iron concentrations - Identified aquifers are relatively deep
GCHP	Moderate	- Soil is mainly saturated glacial tills and gravel - No bedrock near surface to limit borehole depths

The Teslin community well is reported to have a high yield. However, the quality of groundwater yielded by the well is poor, with respect to use for potential GWHP applications. The potential for seasonal fluctuation of water temperatures is not documented. There is a potential that winter groundwater temperatures may be too cold for GWHP applications. *It is recommended that groundwater temperature be continuously monitored at the community well to better assess the potential for GWHP development. In addition, the school well should be inspected and assessed for its potential use in a GWHP system.*

4.15 Town of Watson Lake

4.15.1 Watson Lake Community Description

The Town of Watson Lake (the Town) is located at Kilometre 1,022 of the Alaska Highway at its junction with the Robert Campbell Highway. The Town is approximately 470 km southeast of Whitehorse.

In 1942, the town served as a base for construction of the Alaska Highway. Since the 1940s, Watson Lake has been a service center for the Alaska Highway and for resource developments near the Liard River and its tributaries. Currently, the town is a transportation and communication hub for southern Yukon and northern BC mining and logging operations. Watson Lake is the Yukon's third largest community with a population of 1,545 (Yukon Bureau of Statistics). A location map that shows the town and surrounding topography is shown in Figure 4.15-1. A community profile of Watson Lake appears in Appendix A.

Watson Lake is within Kaska First Nation (KFN) traditional territory and is home to members of the Liard First Nation (LFN). Yukon Energy Corporation supplies electricity to the town using a diesel generating plant that is located adjacent to the Campbell Highway.

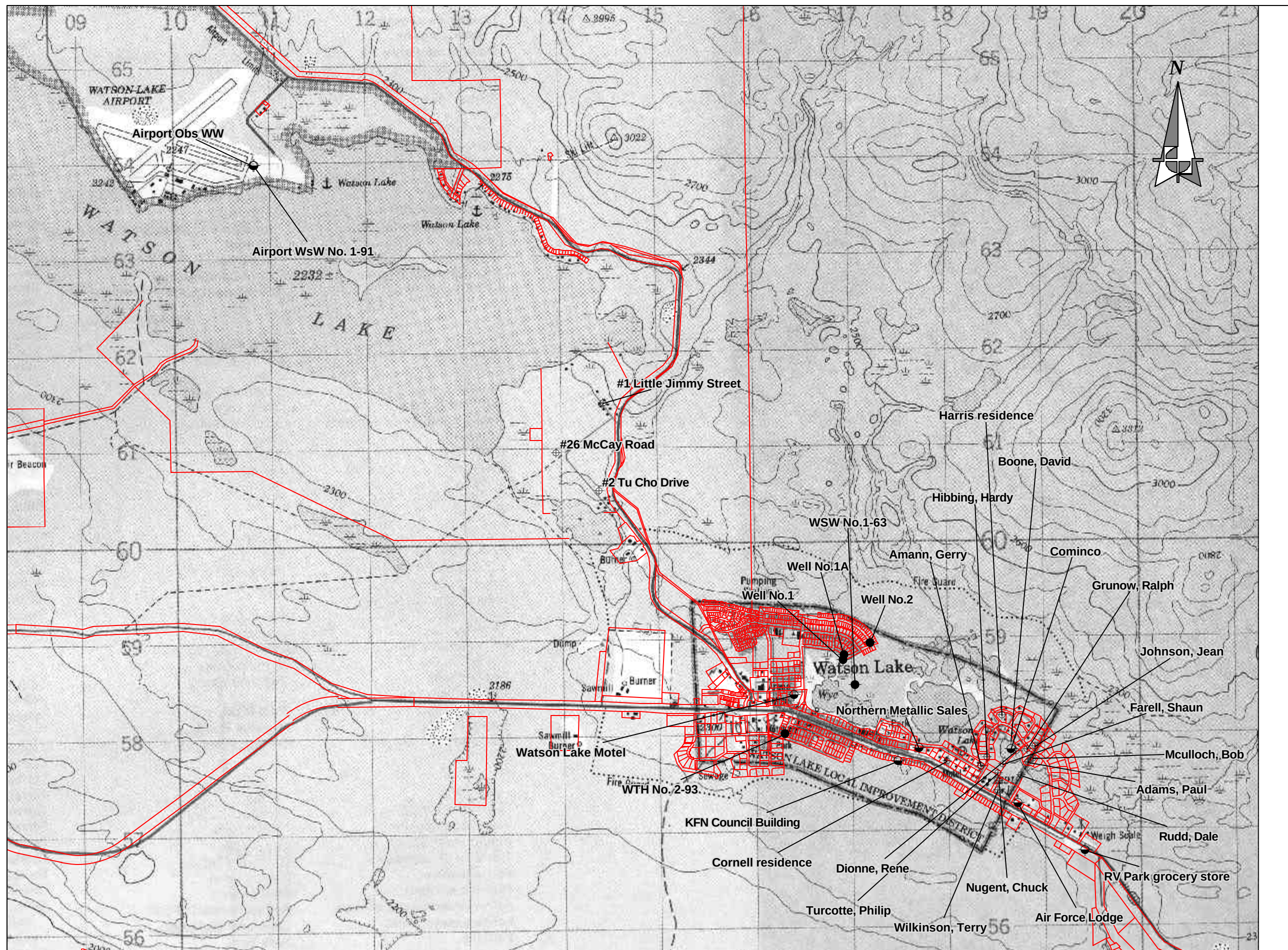
4.15.2 Watson Lake Climate

Climate normal data for Watson Lake for the period 1996 to 2001 are summarized in Table 4.15-1.

Table 4.15-1 Climate Normals for Watson Lake, 1996-2001

Month	Mean Temperatures – Watson Lake (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-18.7	-28.5	-23.6	22.3
February	-9.4	-22.4	-9.7	18.2
March	-2.4	-17.9	-10.2	16.7
April	7.2	-6.7	0.2	24.3
May	13.2	1.7	7.3	36.7
June	19.6	7.3	13.5	59.7
July	21.0	9.1	15.1	65.7
August	19.1	7.3	13.2	53.0
September	12.9	2.7	7.9	40.7
October	3.4	-4.3	-0.9	38.2
November	-9.0	-17.2	-13.1	28.5
December	-12.67	-23.1	-18.2	30.10
Year	3.70	-7.67	-1.5	434.2

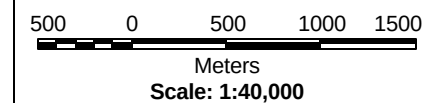
Source: Environment Canada 2002.



LEGEND:

Identified Water Well Locations
(number of wells)

-  Commercial/Institutional (8)
-  Domestic (17)
-  Municipal (5)



Source of Basemap:
Energy, Mines and Resources Canada
1985. National Topographic series 105A/02

Reviewed By: FKP
Drawn By: GC
Date Issued: October, 2003
Project Number: 22680
File Name: 22680_Watson_Fig1_Final.WOR
Revision: 0

Watson Lake Known Well Locations

Yukon Groundwater and Ground Heat
Potential Inventory

Figure No. **4.15-1**

4.15.3 Watson Lake Topography and Hydrology

The town is developed within a relatively flat plateau at an elevation of approximately 700 m amsl. Watson Lake (the eponymous surface water body) is approximately 3 km northwest of town and is the largest nearby surface water body. The nearest surface water bodies are Wye Lake and several other small lakes and wetlands. The Liard River is located approximately 4 km south of town.

4.15.4 Watson Lake Geology

The most recent published results of surficial geology mapping for the Watson Lake area that were reviewed are those of Klassen and Morison (1981). The results of Gartner Lee's terrain analysis are shown on Figure 4.15-2.

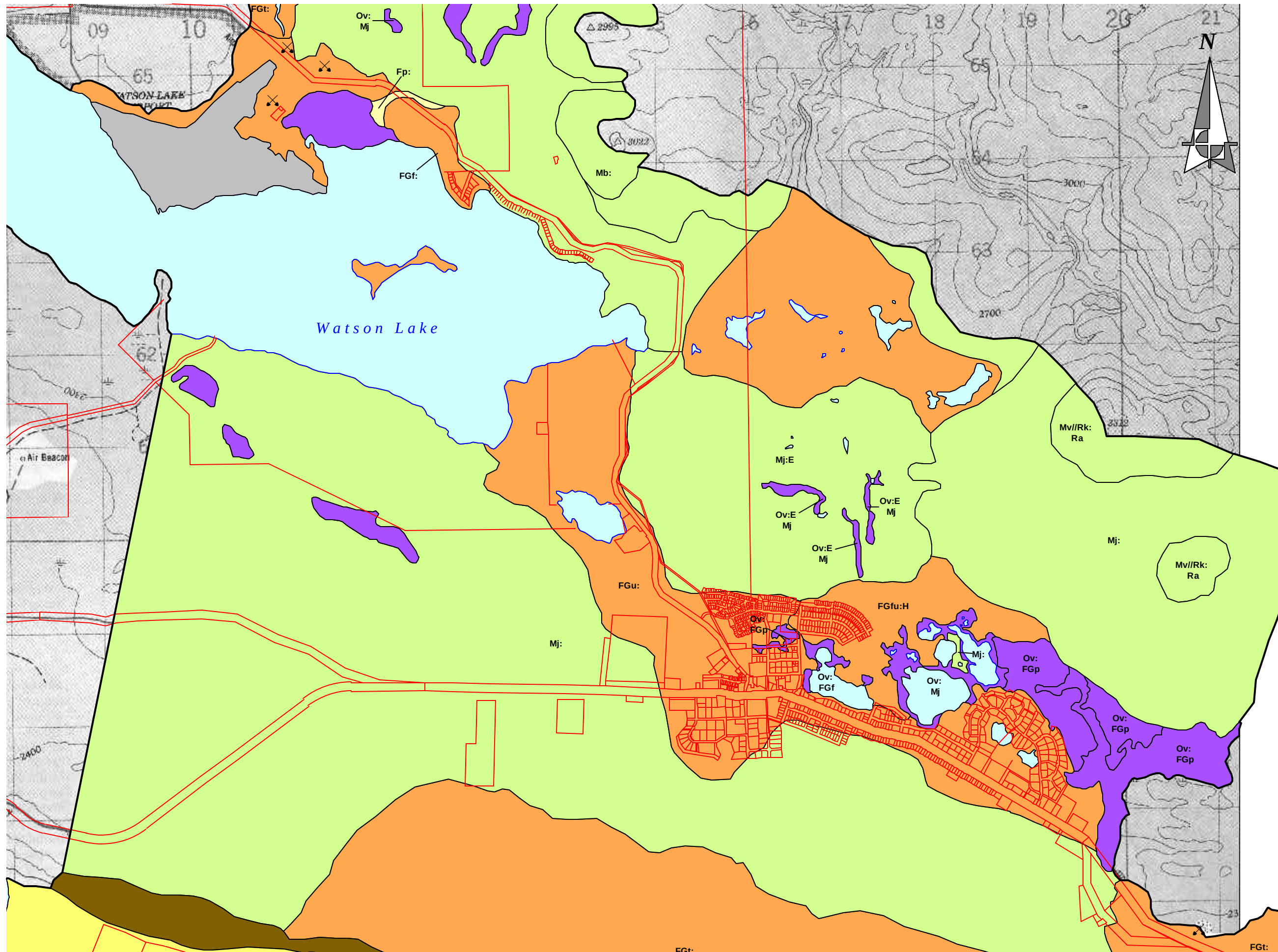
North and south of town, the terrain rises gently to till-covered hills. In town, deposits of glaciofluvial sand and gravel extend to depths of 30 metres below surface at municipal Well No. 1A. As these glaciofluvial deposits are inferred to have been deposited in an ice contact setting, they are likely to be heterogeneous and range from being dominated by boulders, sand and gravel to being silty. These glaciofluvial sediments host the town's water-supply aquifer.

The nearest bedrock exposures occur along the highway to the west and are reported to consist of Tertiary age basalt. Bedrock exposed on hills north of town are described as metasediments (e.g., chert, phyllite and argillite) (Gordey and Makepeace 2000). Bedrock beneath town has been encountered at depths of 69 m and 44 m at (1979) test well Nos. 1 and 2 (Stanley Associates 1980).

4.15.5 Watson Lake Hydrogeology

Locations of identified water wells in Watson Lake are shown on Figure 4.15-1. Identified developed groundwater resources in and near Watson Lake are generally limited to those from shallow unconfined sand and gravel aquifers. Intera (1975) reported that several wells at the airport in town range in depth from 9 m to 21 m. Reported depths to groundwater in these shallow aquifers are typically between 3 m and 5 m. Bottoms of developed aquifers typically occur at a depth of approximately 30 m. Groundwater yield from wells developed in the shallow aquifers is, typically, good. Estimates of aquifer transitivity range between approximately 1,200 m²/day and 2,000 m²/day. Stanley Associates (1977) inferred that community well No. 1A is hydraulically connected to Wye Lake.

It is likely that most shallow unconfined aquifer(s) beneath town are hydraulically connected with nearby surface water bodies. Accordingly, groundwater temperature in these aquifers has a potential to vary



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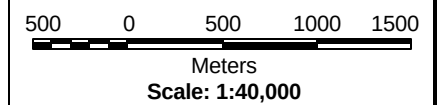
Primary Surficial Material

- A - Anthropogenic
- C - Colluvium
- F - Fluvial
- FA - Fluvial, active
- FG - Glaciofluvial
- M - Morainal (Till)
- O - Organic

Gravel Pit

Extent of Terrain Analysis

Note: See figure 2.2-1 for the Terrain Interpretation Legend



Source of Basemap:
Energy, Mines and Resources Canada
1985. National Topographic series 105A/02

Reviewed By:	FKP
Drawn By:	NS/FKP
Date Issued:	June, 2003
Project Number:	22680
File Name:	Watson_Version2.WOR
Revision:	0

**Watson Lake
Terrain Interpretation**

**Yukon Groundwater and Ground Heat
Potential Inventory**

Figure No. **4.15-2**

Gartner Lee

seasonally and decrease during winter. Analyzed groundwater from town wells is generally hard. In addition, it typically contains elevated concentrations of iron and manganese.

4.15.6 Watson Lake Municipal Water Supply

The town obtains water from three community wells that are north of Wye Lake. Locations of the wells are shown on Figure 4.15-3. According to Government of Yukon (YTG 1991), by 1991, most of Watson Lake was serviced with water from two community wells (which wells is not identified) and the water distribution system was equipped with one 1,130,000 L reservoir and chlorination and fluoridation facilities. In 1991, some private wells in "older" areas of Watson Lake continued to be used (YTG 1991).

Information concerning the Watson Lake municipal wells is summarized in Table 4.15-2.

Table 4.15-2 Details for Watson Lake Community Wells

Well Name	Year Completed	Total Depth (m bgs)	Static Water Level Range (m bgs)	Estimated Aquifer Thickness (m)	Estimated Transmissivity (m ² /day)	Comments
Well No. 1	1963	12.9	3.97 – 6.24	3.7	1,730-2,020	Intera 1975, Stanley Associates 1977, HCL 1996
Well No. 1A	1977	24.2	4.1	-	1,470	Stanley Associates 1977 (referenced as wells W.L. No. 2), HCL 1996
WSW 1-93 (Well No. 2?)	1993	25	6.63	21	1,200	HCL 1996
Observation Well	1963	15.0	4.9	-	-	Stanley Associates 1977, HCL 1996

Note: bgs = below ground surface.

4.15.7 Other Groundwater Supplies

In 2002, most town residents were serviced with municipal water. Private wells are or were utilized as follows:

- Since approximately 1942, several private wells have been installed at the Watson Lake Airport. These wells are inferred to be completed within shallow unconfined sand aquifer(s) immediately north of Watson Lake.
- In 1991, a water well and an observation well were installed at the Watson Lake Airport.
- In 1996, 15 private wells were installed within the Town's Bellevue Phase 1 subdivision. The wells were completed at depths ranging between 4.3 m and 16.5 m.

4.15.8 Watson Lake Groundwater Quality

Based on the results of chemical analyses of groundwater in town wells, overall, groundwater in and near town is classified as hard to very hard according to the classification scheme outlined in section 2. The groundwater typically contains elevated iron and manganese concentrations. Selected groundwater quality information is summarized in Table 4.15-3.

Table 4.15-3 Selected Characteristics of Watson Lake Groundwater

Well	PH	Hardness (mg/L CaCO ₃)	Alkalinity (mg/L CaCO ₃)	Iron (mg/L)	Manganese (mg/L)	Reference
Watson Lake Motel	7.7	168	-	0.27	0.04	Intera 1975
Well No. 1	7.7	191	179	<0.02	<0.02	Intera 1975
	-	226	208	0.01	-	Stanley 1984
	-	208-211	199-206	0.44 - 0.59	0.062 - 0.116	J. Gibson Environmental Consulting 2000
Town Well No. 1A	-	130	140	0.57	0.5	Stanley 1977
	-	207	196	0.25	-	Stanley 1984

In 1996, analyzed groundwater from eight of 15 wells in the Bellevue Subdivision Phase 1 Area contained concentrations of total iron that exceeded 0.3 mg/L. In two of three analyzed samples analyzed, the manganese concentration of the groundwater exceeded the 0.05 mg/L (HGC 1996).

4.15.9 Watson Lake Groundwater Temperatures

Because shallow groundwater beneath Watson Lake is likely to be hydraulically connected to nearby surface water bodies, it is likely that the temperature and chemistry of shallow groundwater beneath Watson Lake fluctuates seasonally. The results of temperature measurements from Town well(s) indicate that between December 1995 and November 1996, the average groundwater temperature was 7 degrees Celsius, the average maximum monthly temperature was 7 degrees Celsius and the average minimum monthly temperature was 2.5 degrees Celsius.

4.15.10 Watson Lake Community Visit

Gartner Lee visited Watson Lake on December 11 and 12, 2002. Activities completed during the visit included the following:

- Gartner Lee visited Mr. Bob McCulloch of the Town. Mr. McCulloch provided access to the three Town wells. Mr. McCulloch did not report any groundwater quality issues other than complaints about staining that is caused by the water.
- Gartner Lee visited Mr. Alfred Chief of LFN. Mr. Lee provided access to three private wells in the LFN 2-Mile and 2 ½-Mile Subdivisions (north of town). Groundwater from these wells that was sampled by Gartner Lee emitted a strong hydrogen sulfide-like odor. In addition, fixtures near the sampling locations displayed what appeared to be iron staining.
- Gartner Lee monitored the Ms. Brenda Cornell private well. Ms. Cornell did not identify groundwater concerns.
- At the recreational vehicle (RV) Park, multiple wells have been completed. Well users interviewed reported that their water is of acceptable quality. Some users reported that the quality of their water was "the best in town".
- Collection groundwater field measurements at the Airforce Lodge. Scale is reported to be a problem for the lodge's water treatment equipment.
- Collection groundwater field measurements at the KFN Council Office. The groundwater is reported to be obtained from a shallow dug well.
- Collection groundwater field measurements at the Harris residence in the Bellview Subdivision. The groundwater was softened prior to monitoring due to reported odor and high iron concentrations.
- Collection groundwater field measurements at the Northern Metallic Sales office. The groundwater is reported to be obtained from a "deep" well. The water is described to be of poor aesthetic quality, the well is described to be poorly maintained and the water is described to be not used for drinking.

During the visit, Gartner Lee measured groundwater field variables at accessible well locations. The results of the monitoring are summarized in Table 4.15-4.

Table 4.15-4 Watson Lake Groundwater Field Parameters Measured on December 11, 2002

Location	Temperature (Degrees C)	pH	Electrical Conductivity (µS)	Field Hardness
Well No. 1	5.4	7.4	465	Hard
Well No. 1A	4.8	7.4	356	Very Hard
Well No. 2	3.8	7.3	455	Very Hard
No. 26 McKay Road	5.1	7.7	349	Very Hard
No. 2 Tu Cho Drive	4.5	7.3	560	Very Hard
No. 1 Little Jimmy Street	5.9	7.5	356	Very Hard
Cornell residence	5.3	7.6	232	Hard
RV Park grocery store	5.3	7.2	446	Very Hard
Air Force Lodge well	4.6	7.4	391	Very Hard
KFN Council Building	4.9	7.3	477	Hard
Harris residence	6.8	7.7	395	Soft
Northern Metallic Sales	5.2	7.2	625	Very Hard

4.15.11 Watson Lake GSHP Potential

GSHP Type	Potential	Comments
GWHP	Moderate to High	- Historically, groundwater has been developed extensively for drinking - Municipal wells are high yield - Seasonal groundwater temperatures may be too cold for GWHP applications due to surface water influence - Groundwater may be hard with elevated iron concentrations
GCHP	Moderate	- Soil is mainly saturated glacial tills and gravel - No bedrock near surface to limit borehole depths

The Watson Lake municipal wells are reported to be of high yield. However, groundwater quality is poor, with respect to potential for use in GWHP applications. Groundwater development in the community appears to be relatively successful. Seasonal water temperature fluctuations are not reported and winter temperatures of shallow groundwater may be too cold for year-round operation of GWHP applications. *It is recommended that groundwater temperature monitoring should be conducted continuously at the community well to better assess the potential for groundwater in the community aquifer for use in GWHP systems. Careful consideration must also be given to groundwater quality when assessing GWHP potential.*

4.16 City of Whitehorse

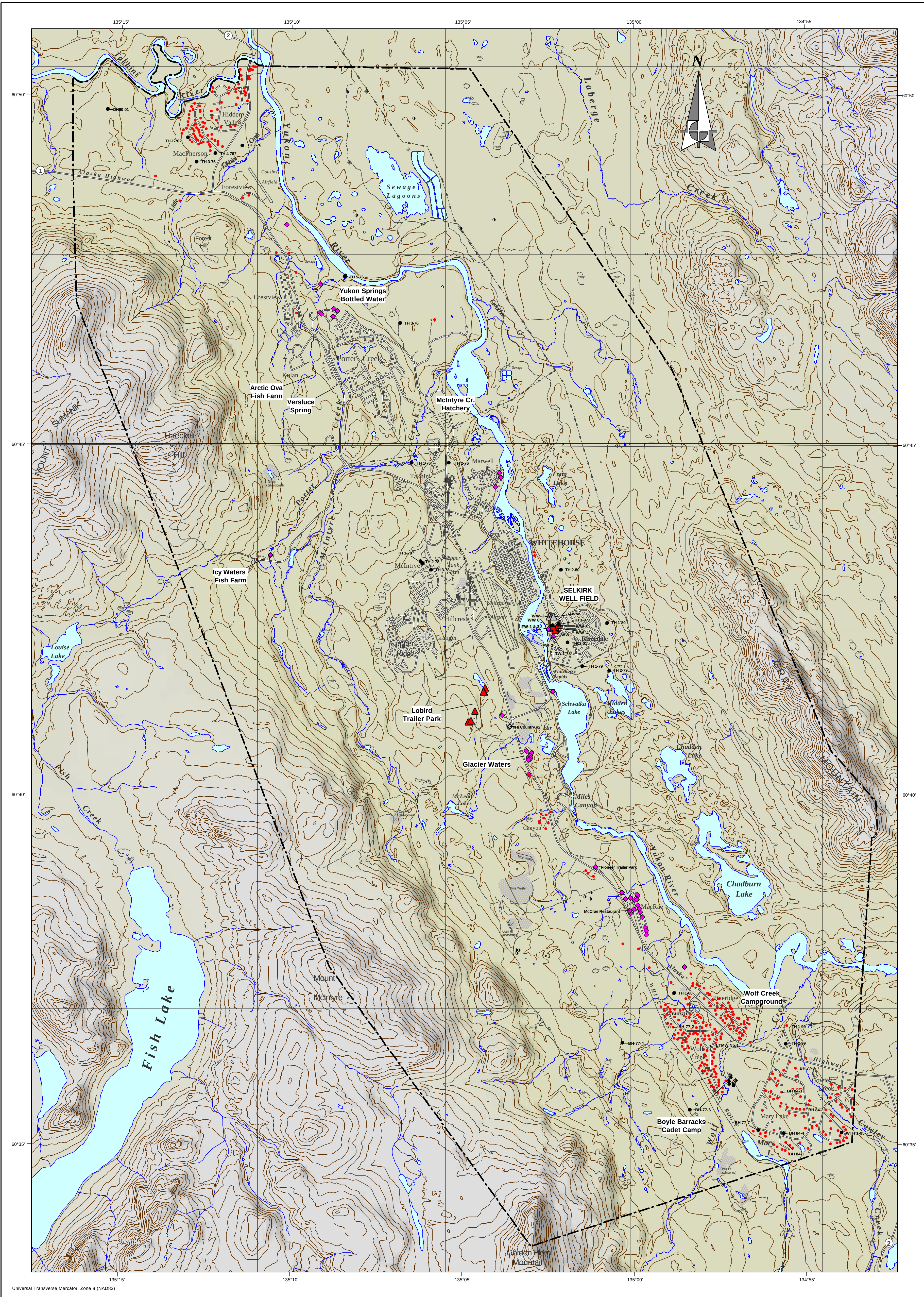
Hydrogeological conditions and groundwater usage in the City of Whitehorse (Whitehorse) are documented in the Gartner Lee report “*Preliminary Groundwater Inventory of the City of Whitehorse*” that was prepared for the City of Whitehorse in 2003. The scope of the preliminary groundwater inventory investigation is more detailed than that presented in this report. The following discussion summarizes key findings that are identified in the preliminary groundwater inventory report. For additional details, the reader is referred to this report.

4.16.1 City of Whitehorse Description

Whitehorse is located in the Yukon River Valley south of Lake Laberge. The city extends approximately 30 km from north to south and 20 km from east to west, encompassing an area of approximately 416 square kilometers. Four 1:50,000 scale National Topographic Series (NTS) maps provide coverage of the city as follows: 105D/10, 105D/11, 105D/14 and 105D/15. The Whitehorse area is dominated by the north-flowing Yukon River, which bisects the Yukon River Valley near the city (Figure 4.16-1).

The landforms of the Whitehorse area are attributable to numerous glacial episodes, the most recent being the McConnell glaciation that occurred between 35,000 and 10,000 years ago. The surficial geology of the Whitehorse area consists of a complex sequence of glacial, glaciofluvial and glaciolacustrine deposits that are typical of deglaciation processes in mountainous terrain. These deglaciation features affect and control the hydrologic and hydrogeological regimes in the study area.

Whitehorse is the capital of the Yukon and is the Yukon’s largest community with population of 19,058 in 2001 (UMA Engineering Ltd. 2002). According to the Yukon Bureau of Statistics (2003), 74 per cent of the Yukon’s population lives in Whitehorse and its periphery. Approximately 91 per cent of the residents of Whitehorse are serviced by the municipal water and sewer system which services the subdivisions of Riverdale, Downtown, Takhini, McIntyre, Granger, Copper Ridge, Arkell, Porter Creek and Crestview. Another 9 per cent of the population lives in rural residential subdivisions. These areas rely on either trucked water delivery, or on-site private water wells and septic fields. Most of the city’s commercial and institutional buildings are located in the Downtown and the Riverdale areas. Outside these areas, other major institutional/commercial buildings include those of the Yukon College campus, seven schools, the Whitehorse Correctional Centre, two ice arenas and the city’s recreation Multiplex. Electrical power for Whitehorse is provided from the Whitehorse-Aishihik-Faro grid, including the Whitehorse Rapid Hydroelectric project just south of the Downtown/Riverdale area.



Universal Transverse Mercator, Zone 8 (NAD83)

LEGEND

KNOWN WATER WELLS *

- Commercial & Industrial
- Domestic Well
- Geotechnical Borehole
- Municipal / Communal
- Observation
- Environmental Monitoring
- Test Well

* Grey indicated well abandoned or not in use.



CITY OF WHITEHORSE
Engineering & Environmental Services



Indian and Northern
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NORTHERN AFFAIRS PROGRAM
Water Resources



GOVERNMENT OF YUKON
Community Development Branch
Environmental Health Services

CITY OF WHITEHORSE KNOWN WELL LOCATIONS

FIGURE 4.16-1

YUKON GROUNDWATER AND GROUND SOURCE HEAT POTENTIAL INVENTORY

NOTE: This figure reproduced from the report entitled "Preliminary Hydrogeological Inventory of the City of Whitehorse", Prepared by Gartner Lee Limited for the Community Development Branch of the Government of Yukon, 2003.

Scale: 1:50,000

1 cm is equivalent to 500 metres



SOURCES OF INFORMATION

Data Compiled by Gartner Lee Limited, 2002.

References:

Cartography by F. Pearson, 2002.

Base map derived from: 1) 1:50,000 map sheets 105D/10, 11, 14 and 105D/15 of the National Topographic Series; and 2) 1:20,000 digital mapping of the City of Whitehorse prepared by Trishon Mapping Corp. (1996).



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Date Issued: Oct. 2003
File Name: 22680-F4_16_1.wor

4.16.2 Whitehorse Climate

Climate normal data for the Whitehorse International Airport, provided by Environment Canada and based on the period between 1996 and 2001, are summarized in Table 4.16-1.

Table 4.16-1 Climate Normals for Whitehorse, 1997-2002

Month	Mean Temperatures – Whitehorse (Degrees Celsius)			Mean Precipitation (mm)
	Maximum	Minimum	Average	
January	-14.84	-26.28	-20.56	7.54
February	-6.66	-21.62	-14.16	5.32
March	-2.28	-18.90	-10.60	5.16
April	5.74	-7.30	-0.76	5.66
May	11.72	-1.88	4.94	23.54
June	18.56	4.78	11.70	53.46
July	19.46	7.02	13.28	62.46
August	17.54	4.46	11.02	42.72
September	9.10	-0.70	4.22	16.32
October	1.28	-9.14	-3.92	24.62
November	-6.84	-17.62	-12.28	9.46
December	-12.70	-24.40	-18.52	13.52
Year	3.34	-9.30	-2.97	269.78

Source: Environment Canada 2002.

4.16.3 Whitehorse Topography and Hydrology

Local topographic relief ranges from 640 m amsl along the Yukon River, to 1,680 m amsl at the peak of Golden Horn Mountain. A series of alluvial plains borders the Yukon River and are developed as the Downtown and Riverdale areas of the city. The landscape rises above the alluvial plains to a discontinuous series of glaciolacustrine terraces at an elevation of approximately 700 m amsl. The Whitehorse International Airport and the Takhini area of Whitehorse are both located on such terraces. Above the glaciolacustrine terraces, the landscape rises to a broad series of rolling upland benches that range in elevation from between 700 m amsl to 800 m amsl. Soil within these upland areas typically consists of till mantling bedrock and is frequently dissected by glacial meltwater channels.

A significant physiographic feature of the Whitehorse area is a long ice-contact or kame-and-kettle terrain that parallels the Yukon River. This feature is roughly divided into two areas: the Chadburn Lake area and the Long Lake area, located south and north of Riverdale, respectively. Within these areas are significant hummocky near-surface deposits of sand, gravel and minor silt.

Surface water flow near Whitehorse is dominated the north-flowing Yukon River. Major creeks within the city include Cowley Creek, Wolf Creek, MacRae Creek, McIntyre Creek, Croucher Creek, Maculey Creek and Little Takhini Creek. Several small creeks flow into ponds that lack surface water outlets. The largest such creek is Porter Creek. Furthermore, several areas lack positive surface water drainage and several areas are characterized by closed draining, such as the Chadburn Lake and Long Lake ice-contact complexes. Both types of “watersheds” are likely important sources of groundwater recharge.

4.16.4 Whitehorse Surficial Geology

The Whitehorse Valley contains a complex sequence of glacial, glaciofluvial and glaciolacustrine deposits that are associated with deglaciation processes in mountainous terrain. Surficial deposits of the city have been mapped at a scale of 1:20,000 by Mougeot GeoAnalysis and Agriculture and Agri-Foods Canada (1996). Figure 4.16-2 is an idealized surficial geology map of the Whitehorse area.

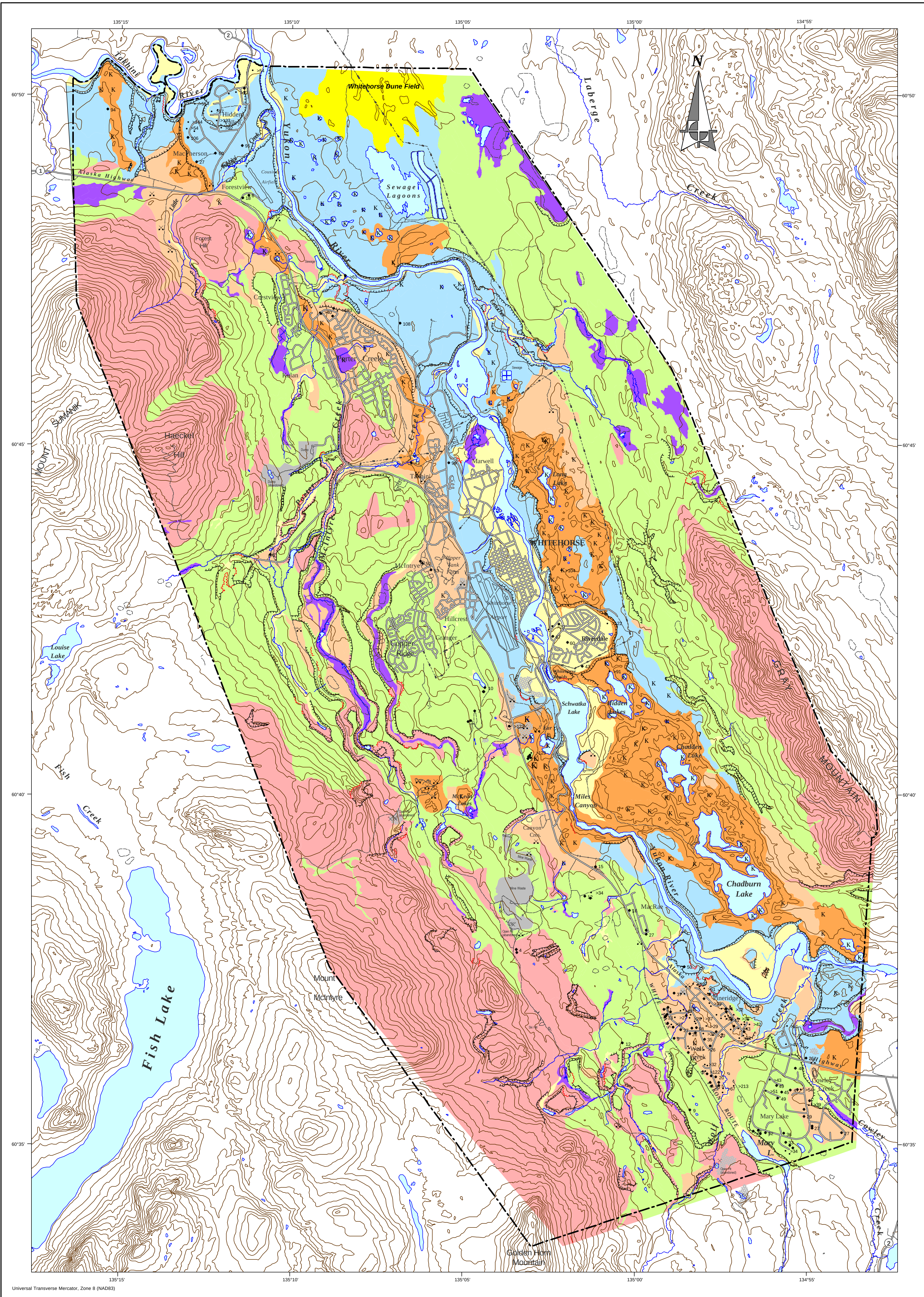
Lowlands adjacent to the Yukon River are underlain typically by fluvial sand and gravel that overlies either glaciofluvial or glaciolacustrine deposits. For example, sand that underlies parts of Riverdale and all of the Downtown area overlies 50 m or more of lacustrine sand, silt and clay.

Glaciolacustrine terraces that are developed above the Yukon River are typically underlain by 3 m to 5 m of uniform glaciofluvial sand that overlies deposits of glaciolacustrine silt and clay. In some areas, such as the Spruce Hill rural residential subdivision, deposits of outwash gravel underlie 35 m or more of glaciolacustrine sediments.

Upland benches near Whitehorse are typically developed on bedrock or are underlain by a blanket of till that directly overlies bedrock. Deposits of sand and gravel, however, are commonly found near the mouths of many of the glacial meltwater channels. These deposits of sand and gravel, known as kame deltas, sometimes overlie lacustrine sediments and occasionally display a pitted surface, which is caused by melting of orphaned ice blocks. Examples of kame deltas include the Wolf Creek-Pineridge subdivision area, the Hillcrest-Valleyview subdivision area, the McIntyre Creek/Yukon College area and parts of the Porter Creek subdivision.

4.16.5 Whitehorse Bedrock Geology

Generally, Whitehorse is underlain by sedimentary and metasedimentary rocks of the Whitehorse Trough Supergroup. These rocks were deposited in a marine environment some 200 million years ago and include both clastic sediments such as sandstone and shale as well as carbonate sediments such as limestone. Following their deposition, the sediments were folded and faulted. Between 110 and 60 million years ago, magmatic rocks intruded the Whitehorse Trough rocks and cooled to form the granitic Whitehorse.



Universal Transverse Mercator, Zone 8 (NAD83)

LEGEND

- SURFICIAL MATERIALS ***
- ORGANIC DEPOSITS - peat and muck associated with wetlands. Deposits vary from fibric to humic, and are usually thinner than 0.5 m.
 - FLUVIAL - gravel, sand and silt associated with modern streams and rivers.
 - EOLIAN DEPOSITS - usually consists of fine sand with minor silt; landform surface is hummocky (dunes).
 - GLACIOLACUSTRINE DEPOSITS - usually consists of fine sand and silt with increasing clay content at depth and occasional sandy to gravelly pockets. Unit is frequently covered with several metres of glacioluvial outwash sand (not shown).
 - GLACIOLUVIAL DEPOSITS - usually consists of well graded sand and gravel, varies from deposit to deposit. It is common to find a silt and/or sand veneer over the gravelly sediment.
 - ICE CONTACT DEPOSITS - consists of heterogeneous mixture of sand, gravel with local deposits of silt. Highly variable composition. Landforms are pitted and very hummocky (same and kettle topography).
 - MORAINEL DEPOSITS (TILL) - usually consists of pebbly to bouldery gravel with a silty, sandy matrix. Clay content in matrix is low. Matrix at depth (greater than 1m) is usually rich in carbonates.
 - BEDROCK - variable. In some areas, the bedrock consists of altered granite (grus) that is similar to a poorly graded pebbly gravel with low matrix content.
 - ANTHROPOGENIC - quarries, rock dumps, mines or other surfaces modified by humans.

* General representation of dominant surficial materials in the top 5 to 15 metres. Veneers and discontinuous materials are not shown.

SYMBOLS

- 51 Bedrock well, approximate thickness of overburden
- <24 Deep well ending in overburden, approximate elevation of well bottom
- K Kettle
- Gravel pit
- Mine, Quarry
- Escarpment
- Landslide headscarp (may not be active)
- City of Whitehorse Municipal boundary

SOURCES OF INFORMATION

Data Compiled by Gartner Lee Limited, 2002.

References:

Cartography by F. Pearson, 2002.

Base map derived from: 1) 1:50,000 map sheets 105D/10, 11, 14 and 105D/15 of the National Topographic Series; and 2) 1:20,000 digital mapping of the City of Whitehorse prepared by Trishon Mapping Corp. (1996).

Surficial geology generalized and updated from Mougout GeoAnalysis and Agriculture and Agri-Foods Canada, 1996, Terrain, soil and wetland mapping. Prepared for the City of Whitehorse. 1:20,000 scale.



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Community Development Branch
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CITY OF WHITEHORSE TERRAIN INTERPRETATION

FIGURE 4.16-2
YUKON GROUNDWATER AND GROUND SOURCE
HEAT POTENTIAL INVENTORY

NOTE: This figure reproduced from the report entitled "Preliminary Hydrogeological Inventory of the City of Whitehorse", Prepared by Gartner Lee Limited for the Community Development Branch of the Government of Yukon, 2003.

Scale: 1:50,000

1 cm is equivalent to 500 metres



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Batholith and Mt. McIntyre Pluton. These rocks were subsequently uplifted, eroded and, in some places, deeply weathered. Less than nine million years ago, lava erupted near the southwest portion of Whitehorse and flowed into the proto-Yukon River Valley. The lava flows currently form the dramatic cliffs of the Miles Canyon and Whitehorse Rapids.

Near Whitehorse, bedrock typically outcrops or subcrops in upland areas above an elevation of approximately 700 m amsl and exposed bedrock forms most of the terrain above an elevation of approximately 800 m amsl. In the centre of the Yukon River Valley, bedrock is not typically exposed; the basalt flows that are exposed at the Whitehorse Rapids and Miles Canyon are an exception. Bedrock underlying most of the Riverdale area is typically found at depths of between 50 m and 120 m or more. Beneath Downtown Whitehorse, bedrock at the Honda geothermal test hole occurs at a depth of 55 m (or an elevation of 192 m amsl) (Gartner Lee 2002).

The Miles Canyon Basalt is the most widely recognized potential bedrock aquifer near Whitehorse. Many homes in the Wolf Creek, Pineridge and Mary Lake subdivisions obtain water from private wells that are completed within aquifers that occur within the basalt. The granitic rocks of the Whitehorse Batholith have a low potential to contain aquifers. However, some homeowners have been successful at completing low-yield wells in the granitic rocks. Many such wells are quite deep. Little is identified regarding the potential of the sedimentary and metasedimentary bedrock of the Whitehorse Trough Supergroup to host aquifers.

4.16.6 Whitehorse Hydrogeology

Hydrogeology, groundwater occurrences and groundwater development potential varies significantly across Whitehorse due to the complex topographic and geological makeup of the area. Hydrogeological conditions within different parts of the Whitehorse area are described on an area by area basis in the following sections, arranged from south to north. Locations of identified water wells in Whitehorse are shown on Figure 4.16-2.

Cowley Creek Area

The Cowley Creek area is a rural residential subdivision at the south end of Whitehorse. No major industrial, commercial or institutional buildings occur in this area. Very little is documented with regard to groundwater resources in this area.

One test well was drilled in 1995 according to HCL (1995). The well encountered granitic bedrock at a depth of 27 m. Anecdotal accounts indicate that wells in this area are frequently deep, low yield and that groundwater is of low (aesthetic) quality (either hard or characterized by a high total dissolved solids content). Anecdotal information suggests that near-surface granitic rocks occur throughout much of this area.

Mary Lake and Spruce Hill Areas

The Mary Lake and Spruce Hill rural residential subdivision areas straddle the Alaska Highway and are bounded to the east by Cowley Creek and by Wolf Creek to the west. Most wells in the Mary Lake area are completed in bedrock granodiorite (typical of the southern part of the subdivision) and basalt (to the north). Depth to bedrock ranges from 35 m or more than 55 m (Thompson Geotechnical Consultants Ltd. 1984). The newer Spruce Hill subdivision to the north is underlain mainly by glaciolacustrine silt and clay to a depth of 45 m to 55 m (Gartner Lee 2000). A small productive sand and gravel aquifer underlies the glaciolacustrine deposits. Most private wells in the area are completed in this aquifer.

The Boyle Barracks Cadet Camp (operated by Department of National Defense) is located adjacent to Wolf Creek west of the Mary Lake subdivision. This camp houses 300 to 400 people over the summer months. Water for the camp is supplied by on-site wells. Camp buildings are equipped with conventional septic disposal systems. Water for the camp is supplied by two 10 m wells that are located less than 5 m from Wolf Creek. Groundwater in the wells is likely derived from a shallow alluvial/glaciofluvial aquifer that is associated with Wolf Creek. Creek water levels near the camp are higher than the water table, indicating that the creek is likely to recharge the local aquifer(s). An unsuccessful test well was drilled to depth 200 m in granodiorite near the south end of the camp and yielded less than 0.05 L/s (0.5 igpm) of water.

Wolf Creek and Pineridge Areas

Groundwater supplies most private domestic water for this area. At least 170 private wells are known to exist. Most wells are completed within an unconsolidated aquifer overlying bedrock or the underlying basalt aquifer. Bedrock is granite beneath the northwest corner of the Wolf Creek subdivision. Depth to bedrock in the Wolf Creek subdivision is typically 10 m to 35 m. Bedrock under the Pineridge subdivision (east of the Wolf Creek subdivision) is typically 40 m to more than 55 m. Well yields and groundwater quality within these areas are generally good. However, there have been some low-yield wells or wells that have required deepening to increase their yield (Gartner Lee 2001).

MacRae Area

The small service-industrial MacRae area is north of the Wolf Creek/Pineridge subdivision area and east of the Alaska Highway. Many businesses in the area are serviced by private wells that are completed in bedrock (typically basalt) that occurs, typically, at depths of between 15 m and 30 m.

Riverdale Area

The Selkirk Aquifer underlies the residential subdivision of Riverdale. This aquifer also supplies municipal water for Whitehorse.

The Selkirk Aquifer is an unconfined glaciofluvial sand and gravel aquifer. Although the distribution of aquifer materials is heterogeneous, the aquifer is very productive. Whitehorse obtains its municipal water

from four wells. The deepest and most productive is Well No. 6, which is 26.8 m deep and is capable of supplying water at a rate of more than 130 L/s. The Whitehorse Rapids Fish Hatchery also derives its water from a deep well that is completed in the Selkirk well field. The hatchery well is capable of producing water at rates of greater than 75 L/s at 5.8 degrees Celsius (Kala Groundwater Consulting 1986). Water from the Selkirk Aquifer is important to both the city and the hatchery due to its warmth relative to winter surface water temperatures. Specifically, the city utilizes its well field primarily during winter months and blends groundwater from the aquifer with cold surface water, thereby raising the distribution water temperature and reducing the propensity for freezing of the municipal water mains.

The Selkirk Aquifer is approximately 50 m thick at the Whitehorse municipal well field. Farther south, at the Vanier School test well, the aquifer thins to a thickness of 5.5 m and it is overlain by 50 m of silt and sand (Gartner Lee 2002). At the south end of the Riverdale subdivision, two test wells (drilled in 1979) encountered the Selkirk Aquifer with thickness ranging from 40 m to more than 90 m. Well yields from both wells were excellent (greater than 30 L/s, according to Stanley Associated Engineering Ltd., 1980). The Selkirk Aquifer does not appear to extend to beneath the east portion of Riverdale, where a test well (No. TH-1-80, drilled in 1980) was advanced to a depth of 122 m. This well did encounter saturated sediments, but it is unlikely that this saturated formation is part of the Selkirk Aquifer (Stanley Associated Engineering Ltd. 1981).

In 1980, a 104 m deep test well was drilled 500 m east of the Whitehorse General Hospital. This well encountered a high-yield aquifer. Although water from this well is likely to be relatively warm, this well yielded poorer quality groundwater than is typical of other wells in the Selkirk Aquifer (Stanley Associated Engineering Ltd. 1981). The current condition of this well is not known to Gartner Lee.

Downtown Whitehorse

Near-surface soil beneath Downtown consists of several metres of fluvial sand and gravel that are underlain by a thick sequence of glaciolacustrine silt and clay. A thermal-response test hole was drilled using mud-rotary methods in 2002 near the north end of Whitehorse. This borehole encountered bedrock at a depth of 55 m (at an elevation of approximately 592 m amsl). Although somewhat coarser sediments were encountered overlying bedrock, the groundwater potential of this material was not tested. (Gartner Lee 2002)

Prior to being serviced with municipal water, many Downtown homes and businesses obtained water from shallow dug wells. None of these wells are known by Gartner Lee to exist. These wells likely collected shallow groundwater from the near-surface fluvial sediments.

Granger, Copper Ridge and McIntyre Areas

The Granger, Copper Ridge and McIntyre areas are residential subdivisions that are developed on upland benches that are west of Downtown and west of the Alaska Highway. The surficial geology in this area

consists primarily of glacial till overlying granitic bedrock. Few details regarding the aquifer potential in this area are identified in the reviewed materials. The potential for groundwater development appears to be low. In 1994, a test well was installed at the Hillcrest reservoir. The borehole in which the well was installed was advanced to a depth of 154 m. Granitic bedrock was encountered at a depth of 71 m and the well produced water at a rate of less than 0.5 L/s (Hydrogeological Consultants Ltd. 1990a).

A large glacial meltwater channel is north of the McIntyre subdivision. In 1978, three test wells were drilled in this area. Results indicated a potential for groundwater development. One well encountered saturated unconsolidated sediments overlying bedrock at a depth of 50 m (Stanley Associated Engineering Ltd. 1978). Immediately east of the meltwater channel is a large kame delta that contains sand and gravel. The Valleyview subdivision, the former Upper Tank Farm area and parts of the Hillcrest subdivision are located within this delta. In 1990, a test well was installed to a depth of 66 m near the northwest corner of the Tank Farm. The well produced water at rates of greater than 5.8 L/s (Hydrogeological Consultants Ltd. 1990b). During the October pumping test, groundwater temperatures fluctuated between 1.2 and 1.4 degrees Celsius. The status of this well is not identified in the reviewed materials.

Several springs feeding Spook Creek are located east of the former location of the Tank Farm and the Alaska Highway. These springs are discharge areas for groundwater from beneath the Hillcrest/Valleyview kame delta and the Hillcrest meltwater channel watershed.

Takhini and Whitehorse International Airport Areas

The Takhini subdivision and Whitehorse International Airport are developed on a broad glaciolacustrine terrace. The terrace is mantled with glaciofluvial sand to a depth of between 5 m and 10 m. The sand is underlain by a thick sequence of varved (finely stratified) silt, clay and fine sand. Numerous small seeps emerge from the escarpment face at the contact between overlying permeable sand and the lower permeability underlying lacustrine deposits. In 1976, a test hole that was drilled at the Whitehorse Correctional Centre encountered 25 m of lacustrine deposits overlying 73 m of till. No unconsolidated sediments suitable for development were encountered (Hydrogeological Consultants Ltd. 1976)

McIntyre and Yukon College Areas

The Whitehorse campus of Yukon College is located on a sand and gravel hill that is bounded by McIntyre Creek to the west and glaciolacustrine terraces to the east. The hill is likely a kame deposit associated with the mouth of the McIntyre Creek meltwater channel. The McIntyre pump house area (the area adjacent to McIntyre Creek and west of the campus), was explored in the early 1970's for groundwater development potential. However, much of this work is poorly documented. Intera (1975) referred to this area as the McIntyre Aquifer. Test drilling in the early 1970's identified groundwater development potential, but the nature of the aquifer(s) was not identified (Hydrogeological Consultants 1976).

Porter Creek Area

The Porter Creek subdivision is developed on a large gravelly terrace in the north part of Whitehorse. This residential area is serviced primarily by municipal water. Some small areas of commercial and service-industrial use are also present. Three schools and one ice arena are located in the area. The area contains several large kettle-like depressions, including Hidden Lake, which is the terminus of Porter Creek. Gartner Lee infers that this area is underlain by gravel that was deposited near the mouth of the Porter Creek-Rabbitsfoot Canyon meltwater channel. The south parts of the Porter Creek Subdivision (Porter Creek “C”) are developed on a till-mantled hill.

During the 1960s, a small groundwater-based system supplied water to the Porter Creek area. The system was abandoned when municipal water became available. Groundwater was obtained from a shallow (10 m) well that was adjacent to Porter Creek near the north terminus of Fir Street. Well yield was reported to be 0.6 L/s and was potentially as high as 1.5 L/s (Intera, 1975). Many of the service-industrial developments in the MacDonald Road area are serviced by on-site wells. Most of these wells are between 40 m and 50 m deep. The wells are completed in soil overlying bedrock, or at the bedrock surface. Depth to bedrock beneath the subdivision varies from 0 m (outcrop) at the Porter Creek Secondary School to more than 90 m in the MacDonald Road area.

A warm spring, locally referred to as the Verslucse Spring, occurs at the south end of the subdivision area immediately southwest of Birch Road. This spring flows at a rate of 1 L/s and, in March 2003, had a temperature of 12 degrees Celsius. The spring flows year round and provides water to three houses. Little is identified regarding the origin and nature of groundwater seepage that discharges at this warm spring (Gartner Lee 2003c). The headwaters of Porter Creek arise from a large spring located approximately 5 km southwest of the subdivision area. These springs supply water to the Icy Waters fish farm.

MacPherson and Hidden Valley Areas

Private wells supply the MacPherson area and approximately one third of the homes in the Hidden Valley area. At least 85 private wells have been installed in these two subdivisions. Wells are typically completed between depths of 50 m and 120 m. Bedrock was encountered at a depth of 104 m at one Hidden Valley borehole location.

4.16.7 Whitehorse Groundwater Usage

Selected groundwater quality information that may be relevant to the operation of GSHP systems in Whitehorse is summarized in Table 4.16-3.

Municipal and Communal Groundwater Usage

In 2001, Whitehorse pumped approximately 1,600,000 m³ from four wells in the Selkirk Aquifer (Gartner Lee 2003). Water from the wells is pumped primarily between October and May. Peak groundwater usage occurs during spring. Groundwater is blended with the surface water to reduce surface water turbidity and to increase the temperature of the municipal water during winter.

Groundwater temperatures range between 7 degrees Celsius to 4 degrees Celsius, however groundwater temperatures are not monitored regularly.

The Lobird trailer court obtains much its water from eight deep wells that are located immediately north of the subdivision. The wells are completed in granite, are up to 215 m deep and are characterized by low yields. The maximum production rate from the well field is 25 L/s. Furthermore, the wells require frequent redevelopment due to sloughing of weathered granite (grus) into the well bore.

The Boyle Barracks Cadet Camp located south of Wolf Creek and immediately west of the Alaska Highway is operated seasonally by the Department of National Defense. The camp hosts up to 400 individuals during summer. Water for the camp is supplied by a 10 m deep well that is completed adjacent to Wolf Creek. Annual (seasonal) production is estimated at 5,000 m³, but winter temperatures are not reported. Static water levels in the wells are below the level of water in Wolf Creek, suggesting that if the creek and the aquifer are hydraulically connected, downward hydraulic gradients are developed between the creek and the aquifer. This may result in low winter groundwater temperature.

Fish Hatcheries

Several fish hatcheries and fish farms occur within Whitehorse as follows:

- The Whitehorse Fish Hatchery. Water is supplied by a 68.3 m deep well that is located in Riverdale and that is completed at the bottom of the Selkirk Aquifer. During the 2001/2002 season, the hatchery used 1,040,520 m³ of water at a constant temperature of 5.8 degrees Celsius. Since 2002, this hatchery has been heated using a Waterfurnace Versatec heat pump running off of water pumped from the hatchery's well.
- The Icy Waters farm. Icy Waters is a commercial fish farm that is west of the Alaska Highway on Fish Lake Road. This farm uses approximately 1,650,000 m³ of water per year that is obtained from a spring that is located immediately northeast of the farm. The spring is one of several springs that are within the headwaters of Porter Creek. The temperature of groundwater from the springs is between 3 degrees Celsius and 5.5 degrees Celsius.
- The Arctic Ova Fish Farm. The farm is located immediately south of the Kulan Industrial Subdivision. This farm obtains its water from a small dugout located in the thalweg of a glacial meltwater channel. The water flows year round. However the temperature and quantity of water used is not known to Gartner Lee.

- The McIntyre Incubation Station is a small salmon incubation station that is operated by Department of Fisheries and Oceans. The station is located adjacent to McIntyre Creek immediately west of Mountain View Drive. The station obtains water from a small spring that discharges at rates of between 430 m³/day and 720 m³/day. The temperature of groundwater from the springs ranges between 2 degrees Celsius to 6 degrees Celsius. (Gartner Lee 2003).

Commercial

Many highway-commercial operations outside of the serviced area of Whitehorse obtain water from private wells. Most of these operations are unlikely to use large volumes of water because large-scale manufacturing that consumes large quantities of water does not take place at these operations. Several private commercial wells occur within the MacRae subdivision and in the MacDonald Road area of Porter Creek. The two notable commercial water uses include:

- The Glacier Water's bottling and trucked water delivery services well. This well is located between Ear Lake and the Alaska Highway. Water for this operation is obtained from three wells, each of which is completed at a depth of approximately 100 m. Well yields and groundwater temperatures are not reported in the reviewed materials. However groundwater usage is estimated to be at least 125 m³/day to 150 m³/day.
- Yukon Springs' bottling operation. The operation is located east of the Crestview subdivision. This business uses approximately 1,500 m³/year that is obtained from a shallow spring collector that is located on the property. The discharge rate from the spring is approximately 115 m³/day. The temperature of the spring water is not identified in the reviewed materials (Gartner Lee 2003).

Rural Residential

Approximately 9 per cent of the population of the Whitehorse area live in rural-residential settings (UMA Engineering Ltd. 2001). Most commonly, this proportion of the population lives in subdivisions that are not supplied with municipal water or sewers. Many such homeowners obtain water from private wells and most utilize conventional septic systems for disposal of household septage. Some households obtain water from a delivery truck.

Table 4.16-2 (reproduced from Gartner Lee 2003) summarizes estimates of the number of domestic water wells in Whitehorse and the associated groundwater usage.

Table 4.16-2 Estimated Number of Private Water Wells and Associated Groundwater Usage

Subdivision	Estimated No. of Water Wells	Estimated Total Groundwater Usage (m ³ /year)
Cowley Creek	32	8,678
Mary Lake & Spruce Hill	57	15,458
Wolf Creek	116	31,457
Pineridge	55	14,916
MacRae, Canyon Crescent and McLean Lake	12	3,254
MacRae Industrial *	17	12,410
MacPherson	49	13,289
Hidden Valley & Mayo Road	33	8,950
Other	12	3,254
Total	334	98,380

Notes: * Assume industrial/commercial wells utilize 2 m³/day.

Source: Preliminary Groundwater Inventory of the City of Whitehorse, Gartner Lee 2003.

4.16.8 Quality of Groundwater in Whitehorse

The (aesthetic) quality of groundwater in Whitehorse is generally good but variable. Groundwater from the Selkirk Aquifer and from the Wolf Creek aquifers is described to be of high (aesthetic) quality. Poorer (aesthetic) quality groundwater is reported to occur beneath the Mary Lake and Cowley Creek subdivisions, however this is not well documented. The (aesthetic) quality of groundwater beneath the north part of Whitehorse is not identified in the reviewed materials.

Selected groundwater quality information that may be relevant to the operation of GSHP systems is summarized in Table 4.16-3:

Table 4.16-3 Selected Characteristics of Whitehorse Groundwater

Area (Well)	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Cowley Creek	7.9	153	157	0.71	-	Hydrogeological Consultants 1995
Mary Lake	8.2 - 8.3	344 to 370	197 to 333	0.043 to 5.13	0.014 to 0.75	Thompson Geotechnical Consultants 1984
Spruce Hill	8.2	235 to 263	231 to 234	0.1	0.022 to 0.089	Gartner Lee 2000b
Wolf Creek & Pineridge	8.1 - 8.4	89 to 255 (median = 131)	92 to 182 (median = 127)	<0.03 to 196 (median = 0.08)	<0.001 to 0.058 (median = 0.0045)	Gartner Lee 2003d
MacRae	8.0	130	118	0.05	-	Intera 1975
Selkirk Aquifer	7.5 - 8.4	86 to 210 (median = 116)	85 to 170 (median = 105)	<0.03	<0.001 to 0.008	Gartner Lee 1999, 2000a, 2001c & 2003b

Yukon Groundwater and Ground Source Heat Potential Inventory

Area (Well)	pH	Total Hardness (mg/L CaCO ₃)	Total Alkalinity (mg/L CaCO ₃)	Total Iron (mg/L)	Total Manganese (mg/L)	Reference
Valleyview (WTH No. 2-90)	-	197	200	<0.05	0.002	Hydrogeological Consultants 1990b
McIntyre Cr. Well	-	155	-	-	-	Intera 1975
Versluce Spring	8.0	164	166	<0.03	<0.002	Gartner Lee, 2003c
Porter Creek Well	7.3	206	-	0.1	-	Intera 1975

4.16.9 Whitehorse GSHP Potential

Summary of GSHP Potential for the City of Whitehorse

Area	GSHP Type	Potential	Comments
Cowley Creek	GWHP	Moderate to Low	Wells are often deep, low yield and produce water of poor quality.
	GCHP	Low to Good	- Soils underlying area vary from unsaturated sands to glacial tills. - Bedrock at surface may allow for completion of boreholes in granite - Near surface bedrock (e.g., >2 m below surface) may limit borehole depths
Spruce Hill	GWHP	High	High yield aquifer with relatively good water quality at depth represent an exceptionally good potential opportunity.
	GCHP	Low	Soils underlying area are primarily silt and clay.
Mary Lake	GWHP	Moderate to High	- Northern portion of subdivision may have wells completed in basalt which would be suitable for GWHP application. - Other portions of subdivision may have wells of limited yield similar to Cowley Creek area.
	GCHP	Low to Moderate	- Soils underlying community vary from unsaturated sand and gravel to gravelly till - Bedrock near surface limits borehole depths.
Wolf Creek / Pineridge	GWHP	High	- Most areas have groundwater supplies adequate to support residential GWHP applications. - Water quality generally good
	GCHP	Low to Moderate	- Soils underlying community vary from unsaturated sand and gravel to gravelly till - Bedrock near surface in some areas may limit borehole depths.

Yukon Groundwater and Ground Source Heat Potential Inventory

Area	GSHP Type	Potential	Comments
MacRae	GWHP	High	Most areas have groundwater supplies adequate to support residential GWHP applications.
	GCHP	Low to Moderate	- Soils underlying community are primarily fine grained - Soils underlying community vary from unsaturated sand and gravel to gravelly till - Bedrock near surface in some areas may limit borehole depths.
Riverdale	GWHP	High	- High yield Selkirk Aquifer with warm groundwater temperatures represents an exceptionally good potential opportunity. - Many commercial/institutional buildings as potential users of GSHP technology
	GCHP	Moderate	Soils underlying community vary from saturated sand and gravel to saturated fine sand and silt
Downtown	GWHP	Low	No identified aquifers suitable to support GWHP systems.
	GCHP	Low to moderate	- Soils are primarily fine grained (Thermal conductivity = 1.07 Btu/hr-ft-° F) (Groundsolar Geotechnics 2002) - No bedrock near surface to limit borehole depths.
Granger/Copper Ridge	GWHP	Low	No significant identified aquifers suitable to support GWHP system.
	GCHP	Low	- Soils underlying community are primarily unsaturated glacial till - In some areas near surface bedrock may limit borehole depths.
McIntyre	GWHP	Moderate	Some groundwater potential associated with the “Hillcrest Meltwater Channel” and kame delta, however winter groundwater temperatures may be low
	GCHP	Low to Moderate	Soils underlying community vary from sand and gravel to glacial till
Takhini / Airport	GWHP	Low	No identified aquifers suitable to support GWHP systems.
	GCHP	Low to Moderate	- Soils underlying community are primarily fine grained and may not be saturated. - No bedrock near surface to limit borehole depths.
McIntyre Creek/Yukon College	GWHP	Moderate to High	- Some groundwater development potential, however no recent exploration. - Groundwater temperatures are not reported - Depth to groundwater is not reported for the Yukon College area.
	GCHP	Low to Moderate	- Soils underlying community are primarily coarse grained, but may be unsaturated in Yukon College area. - No bedrock near surface to limit borehole depths.

Yukon Groundwater and Ground Source Heat Potential Inventory

Area	GSHP Type	Potential	Comments
Porter Creek	GWHP	Low to High	- Some areas have (e.g., MacDonald Rd.) good groundwater potential, but drilling may be relatively deep - Groundwater temperatures and quality not identified - Other areas of Porter Creek have limited groundwater potential. - Versluc Spring produces good quality warm water.
	GCHP	Low to Moderate	- Soils underlying community are primarily coarse grained, but unsaturated - Bedrock near surface in some areas may limit borehole depths.
Kulan	GWHP	Low	No identified aquifers are suitable to supply GWHP system
	GCHP	Low to Good	- In areas where bedrock is at surface, good potential for completion of boreholes in bedrock - Other areas of shallow overburden (>2 m) may limit cost effective borehole drilling.
Crestview	GWHP	Low	No identified aquifers in subdivision area suitable to supply GWHP system
	GCHP	Low	- Soils underlying community are likely coarse grained - Shallow bedrock in some areas may limit borehole depths
MacPherson / Hidden Valley	GWHP	Moderate	- Groundwater development for residential purposes seems relatively successful - Drilling depths may be deep, especially in Hidden Valley area - Very little is reported regarding well yields or water quality
	GCHP	Low to moderate	- Soils underlying community are primarily fine grained - No bedrock near surface to limit borehole depths.

Based on the observations presented above, several high priority GSHP opportunities have been identified as follows. Recommendations for follow up are presented:

- Whitehorse - Riverdale/Selkirk Aquifer**

The high yield nature and good quality water that is produced by wells that are completed in the Selkirk aquifer combined with the presence of many schools, apartment complexes and institutional buildings in the Riverdale area provides an obvious opportunity for GSHP applications. A feasibility study for a GWHP project at the Vanier School has been completed (Gartner Lee 2003). The Whitehorse Rapids Fish Hatchery is currently using a heat pump for heating. There is likely opportunity for further development of this resource, but careful management will be required to protect the City's potable water supply and ensure that all users' needs are met. *It is recommended*

that further GWHP opportunities be pursued for the other schools and institutional buildings in the Riverdale area, including Grey Mountain Primary School, implementation of the Vanier School project, Christ the King Secondary School, Council for Yukon First Nations offices, Selkirk Elementary School and F.H. Collins Secondary School. The last four are near Whitehorse's municipal well field. These GWHP opportunities may be suitable for development in co-operation with Whitehorse such that the reject water from the heat pumps could be used for municipal water supply.

- **Whitehorse General Hospital**

The 1980 test well (TH 2-80) is located 450 m east of the hospital. This well was reported to have significant yield, however, had some hardness or elevated concentration of iron and manganese (Stanley Associates 1980). This well or aquifer represents an excellent GWHP opportunity for the hospital. *It is recommended that a feasibility study be completed to assess the potential application of GWHP at the Whitehorse General Hospital.*

- **Whitehorse Multiplex**

The expansion of Whitehorse's recreational Multiplex on Hamilton Boulevard represents a GWHP application opportunity. This would consist of utilizing the 1990 test well at the corner of Hamilton Blvd. and Sumanik Drive. This well may be too far from the construction site, but a desktop/preliminary feasibility study should be completed to assess this potential opportunity. *It is recommended that this test well be located and inspected prior to pursuing this opportunity.*

- **Whitehorse - Hidden Valley School**

Anecdotal accounts suggest that a test well was installed at Hidden Valley School. Information regarding this test well was not located during the present investigation. The potential for GWHP application at this site should be assessed. There may be potential for higher-yield aquifers at depth at this site. *It is recommended that information on the Hidden Valley School test well be obtained and reviewed in the context of assessing GWHP potential.*

5. Bibliography

5.1 General

Federal-Provincial Working Group on Groundwater, 1991:

Guidelines. Groundwater Data Management. Environment Canada. Ottawa, Ont.

Gartner Lee Limited 2001:

Resources. Gartner Lee Project 20-912. Whitehorse, Yukon.

Howes, D.E. and E. Kenk, 1997:

"*Terrain Classification System for British Columbia (Version 2)*", Recreational Fisheries Branch, Ministry of Environment and Survey and Resources Mapping Branch, Ministry of Crown Lands. Province of British Columbia. Victoria, BC.

Kavanaugh, S.P. and K. Rafferty, 1997:

Ground-Source Heat Pumps: Design of Geothermal Systems for Commercial and Institutional Buildings. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., Atlanta, Georgia.

Yukon Bureau of Statistics, 2003:

Yukon Monthly Statistical Review, August, 2003. Government of Yukon. Whitehorse, Yukon.

5.2 Beaver Creek

Government of Yukon (YTG), 2000

"*Yukon Statistical Review – 2000 Annual Report*", YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

"*Community Profiles*", YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

"*Groundwater Management Study of the Yukon Territory*", January 1975.

UMA Engineering Ltd. (UMA), 1993

"*Beaver Creek Street Upgrading, Phase 1: Drainage Study*," October 1, 1993

Underwood McLellan Ltd. (Underwood), 1979

"*Beaver Creek Community Development Plan*", 1979

David Nairne and Associates Ltd. (DNAL), 1990 (Draft)

"Beaver Creek Community Plan", December 1990 Draft Report.

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited (NovaTec), 2002

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities". Final Report, White River First Nation. First Nation

Rampton, V.N., 1978a:

"Surficial Geology and Geomorphology, Koidern Mountain, Yukon Territory", Map 5-1978. Geological Survey of Canada. Ottawa, ON. Map at 1:100,00 scale.

5.3 Burwash Landing

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited, 2002a:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities, Kluane First Nation", Gartner Lee 21-939, February 2000.

Government of Yukon (YTG), 2000

"Yukon Statistical Review – 2000 Annual Report", YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

"Community Profiles", YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Rampton, V.N., 1978b:

"Surficial Geology and Geomorphology, Burwash Creek, Yukon Territory", Map 6-1978. Geological Survey of Canada. Ottawa, ON. Map at 1:100,00 scale.

National Topographic System (NTS) Map 115 G/7 (scale 1:50,000, contour interval 100 feet, North American Datum 1927; 1973);

Rampton, V.N., 1978c:

"Surficial Geology and Geomorphology, Congdon Creek, Yukon Territory", Geological Survey of Canada Map 8-1978, scale 1:100,00.

David Nairne & Associates Ltd. (DNAL), 1989:

"Community Profile and Analysis for Burwash Landing Community Plan Update and Kluane Tribal Council Capital Management Plan and Kluane Tribal Council Bill C-31 Impact Study", for Kluane Tribal Council. Whitehorse, YT.

5.4 Carcross

Stanley Associates Environmental Ltd. (Stanley Associates), 1988:

"Assessment of On-Site Sewage Disposal, surface Water and Groundwater Contamination, Carcross, Yukon", report submitted to YTG, Municipal Engineering Department May 26, 1989.

Associated Engineering Services Ltd. (AES) , 1980:

"Water Supply and Sewage Disposal, Carcross Indian Village, Yukon", report for Department of Indian and Inuit Affairs, Whitehorse, Yukon dated June 1980

EBA Engineering Consultants Ltd. (EBA), 1988:

"Final Report, Hydrogeological Study, Carcross, Yukon", report for YTG, Department of Community & Transportation Services dated December 1988 (EBA project no. 0201-4858).

Gartner Lee Limited and G.J. Bull & Associates Inc. (BA), 2002:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Carcross Tagish First Nation", report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Hydrogeological Consultants Ltd. (HCL), 1994:

"Government of the Yukon, Proposed Sewage Lagoon Site, Carcross Area, 1994 Hydrogeological Study", report for YTG dated August 1994 (HCL project no. 94-132.

HCL, 1976:

"Town of Carcross, 1976 Water Well", report for YTG dated November 1976.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

David Nairne & Associates Ltd. (DNAL), 1993:

"Assessment of the Existing Garbage Dump, Carcross, Yukon" report for Community & Transportation Services, Municipal Engineering Branch dated June 1993.

Piteau Engineering Ltd. (Piteau) and Integrated Environments, 1989:

"Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

UMA Engineering Ltd. (UMA), 1989:

"Carcross Water and Wastewater Predesign, Final Report", report dated September 1989 (UMA project no. 1539-074-00-02).

Yukon Community Profiles (YCP). 2002:

"The Communities of Carcross and Tagish", <http://www.yukoncommunities.yk.ca/watson.html> (November 27, 2002).

Yukon Bureau of Statistics (YBS), 2002:

"Yukon Statistical Review, 2000 Annual Report", report for the Yukon Government Executive Office Bureau of Statistics dated December 2000.

Yukon MINFILE, 2001:

"Mineral Occurrence Map 105D", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5.5 Carmacks

G.J. Bull & Associates Inc. (BA), 2002:

"Village of Carmacks, Assessment of Potential Contamination of Wells Within the Sewered Area, Final Report", report for Village of Carmacks dated February 2002 (BA project no. 1006.03 Task 9.8).

EBA Engineering Consultants Ltd. (EBA), 2001:

"Desk-Top Hydrogeological Study, Carmacks, Whitehorse, YT", report for Village of Carmacks dated Jun 2001 (EBA project no. 0201-01-14927).

Gartner Lee Limited (Gartner Lee) and G.J. Bull & Associates Inc. (BA), 2002:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Little Salmon Carmacks First Nation", report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Martin, R., 2003:

Personal Communication. Conversation between Mr. Ryan Martin (EBA Engineering Consultants Ltd.) and Mr. F. Pearson (Gartner Lee Limited) held in September 2003. Whitehorse, Yukon.

Piteau Engineering Ltd.(Piteau) and Integrated Environments, 1989:

"*Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon*", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

UMA Engineering Ltd. (UMA), 1988:

"*Infrastructure Study, Water and Sewage System, Little Salmon/Carmacks Indian Village, Carmacks, Yukon*", report dated March 1988 (UMA project no. 1539-059-00-02).

Yukon Community Profiles (YCP). 2002:

"*The Community of Pelly Crossing*", <http://www.yukoncommunities.yk.ca/watson.html> (November 27, 2002).

Yukon Bureau of Statistics (YBS), 2000:

"*Yukon Statistical Review, 2000 Annual Report*", report for the Yukon government Executive Office Bureau of Statistics dated December 2000.

Yukon MINFILE, 2001:

"*Mineral Occurrence Map 115I*", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5.6 Dawson

Government of Yukon (YTG), 2000

"*Yukon Statistical Review – 2000 Annual Report*", YTG Executive Council Office, Bureau of Statistics, December 2000.

Gordey, S.P. and Makepeace, A.J., 1999

Yukon Digital Geology, S.P. Gordey and A.J. Makepeace (comp.); Geological Survey of Canada, Open File D3826, and Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1999-1(D)

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited (NovaTec), 2002

"*Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities, Final Report, Tr'ondek Hwech'in First Nation*"

City of Dawson, 1991.

"*Klondike Valley Water Quality Assessment, Final Report*" dated July 1991

STC Shitec Consultants Ltd., 1991

"1991 Water and Sewer Study, City of Dawson"

Archer, Cathro & Associates Ltd., 1985

"Report on the Distribution of Asbestos in Bedrock, Dawson, YT" dated November 15, 1985

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

Groundwater Management Study of the Yukon Territory. January 1975.

Enkon Environmental Limited, February 2002

"City of Dawson Annual Water License Report, 2001", project No. 1120-003

Duk-Rodkin, A. 1996:

"Surficial Geology, Dawson, Yukon Territory", Geological Survey of Canada. Open File 3288. Scale, 1:250,000.

5.7 Destruction Bay

Government of Yukon (YTG), 2000

Yukon Statistical Review – 2000 Annual Report, YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

Groundwater Management Study of the Yukon Territory. January 1975.

Hydrogeological Consultants Ltd. (HCL), 1978.

"Destruction Bay, Yukon Territory, Water Well No. 3, 1978"

Underwood McLellan Ltd. (Underwood), 1979

"Destruction Bay, Yukon Community Development Plan, May 1979"

National Topographic System (NTS) Map 115 G/7 (scale 1:50,000, contour interval 100 feet, North American Datum 1927; 1973);

Rampton, V.N., 1978c:

"Surficial Geology and Geomorphology, Congdon Creek, Yukon Territory", Geological survey of Canada Map 8-1978, scale 1:100,000 scale.

5.8 Faro

Associated Engineering Services Ltd. (AES), 1979:

"Town of Faro. Waterworks, Sewerage, Roadway and Drainage For Townsite Expansion, for the Town of Faro, Yukon" dated December, 1979

AES, 2000:

"Annual Water Use Report 1999 – Faro Water License Renewal – exhibits, MN00-030", report for Town of Faro, Report No. 426.

AES, 1979a:

"Town of Faro, Waterworks, Sewerage, Roadway and Drainage for Townsite Expansion", report for the Town of Faro, Yukon dated December 1979.

Bond, J.D., 2001:

"Quaternary Geology and Till Geochemistry of the Anvil District (Parts of 105K/2, 3, 5, 6 and 7), Central Yukon Territory", Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Bulletin 11, Whitehorse, Yukon

EBA Engineering Consultants Ltd. (EBA), 1981a:

"Geotechnical Evaluation – Proposed 1981 Trailer Park, Faro, Yukon", report for YTG, Department of Municipal and Community Affairs, dated May 1981 (EBA project no. 101-3173).

Gartner Lee Limited, 2002a:

"Anvil Range Mine Complex, 2002 Baseline Environmental Information", report for Deloitte & Touche Inc., Gartner Lee project no. 22-943, Toronto, Ontario.

Government of Yukon (YTG), 2000

"Yukon Statistical Review – 2000 Annual Report", report for YTG Executive Council Office, Bureau of Statistics dated December 2000.

Government of Yukon (YTG), 1991

"Community Profiles", YTG Community and Transportation Services document dated May 15, 1991.

Interra Environmental Consultants Ltd. (Interra), 1975a:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Pigage, L.C., 2001:

"Geologic Map of Faro (NTS 105K/3 NW) & Mt. Mye (NTS 105K/6 SW), Central Yukon", Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 2001-26, Whitehorse, Yukon, scale 1:25,000.

Piteau Engineering Ltd. (Piteau) and Integrated Environments, 1989:

"Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

Stantec Consulting Ltd. (Stantec), 1999:

"Town of Faro Water and Sewer Systems Study", report dated December 1999.

Town of Faro, 1977:

"Inventory and Analysis, Volume II" Town of Faro, Yukon.

Town of Faro, 2000:

"Town of Faro Water License Renewal, MN00-030" dated July 14, 2000.

Yukon MINFILE, 2001:

"Mineral Occurrence Map 105K", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5.9 Haines Junction

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited (NovaTec), 2002a

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities, Final Report, Champagne and Aishihik First Nations".

Gartner Lee Limited, 2002b:

"Haines Junction Water Well No. 5 Completion Report". Gartner Lee project no. 22-345, for the Village of Haines Junction

Government of Yukon (YTG), 2000

Yukon Statistical Review – 2000 Annual Report, YTG Executive Council Office, Bureau of Statistics, December 2000.

Intra Environmental Consultants Ltd. (Interra), 1975:

Groundwater Management Study of the Yukon Territory., January 1975.

Rampton, V.N., and S. Paradis, 1981:

"Surficial Geology and Geomorphology, Pine Lake, Yukon Territory", Geological Survey of Canada Map 16-1981, scale 1:100,000.

Stanley Associates Engineering Ltd. (Stanley Associates), 1980

"Warm Water Well No. 2 Haines Junction, Yukon Territory"

Associated Engineering Services Ltd. (AES), 1963

"Preliminary Report on Water and Sewer Services, Haines Junction, YT."

EBA Engineering Consultants Ltd. (EBA), 1974.

"Haines Junction Water Tower and Pumphouse Geotechnical Evaluation" dated July 1974.

UMA Engineering Ltd. (UMA), 1988

"Village of Haines Junction Water System Improvements, Status Report and Improvement Options, Final Draft" dated 1988.

5.10 Keno

Burn, C.R. 1991.

"Short Communication: Permafrost and Ground Ice Conditions Reported During Geotechnical Investigations in the Mayo District, Yukon Territory." *Permafrost and Periglacial Processes, Vol. 2:* 259-268.

Gordey, S.P. and Makepeace, A.J., 1999

Yukon Digital Geology, S.P. Gordey and A.J. Makepeace (comp.); Geological Survey of Canada, Open File D3826, and Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada, Open File 1999-1(D)

Government of Yukon (YTG), 2000

Yukon Statistical Review – 2000 Annual Report, YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Government of Yukon (YTG) Community and Transportation Services, December 3, 1987

Internal Memo, File MA 5800-K1.

Intera Environmental Consultants Ltd. (Interra), 1975:

Groundwater Management Study of the Yukon Territory. January 1975.

National Topographic System (NTS) Map 105 M/14 (scale 1:50,000, contour interval 100 feet, North American Datum 1927; 1971);

<http://www12.statcan.ca/english/profil101/details/details1pop.cfm> (December 14, 2002);

5.11 Mayo

Associated Engineering Services, Ltd. (AES), 1982

"Government of Yukon, Water Systems Improvements, Mayo, Yukon" dated January 1982

Hydrogeological Consultants Ltd. (HCL), 1980

"Mayo 1975 Warm Water Well Servicing" dated January, 1980

Yukon Groundwater and Ground Source Heat Potential Inventory

MLM Ground-Water Engineering, 1990

"Construction and Testing of Warm Water Well PW 2, Mayo, Yukon" for Stanley Associates Engineering Ltd., MLM reference No. 90e-353-1, August 27, 1990

Quanta Labs, 1988

"Chemical Analysis Report, Work Order 9013", completed April 11, 1988

Reid Crowther & Partners Limited (RCAPL), EBA. Engineering Consultants, 1985.

"Heat Pump Opportunities for Mayo, Yukon. A Feasibility Study of Geothermal Options" dated March 1985

Stanley Associates Engineering Ltd. (Stanley Associates), 1987.

"Village of Mayo (Draft) Design Brief of Water Systems Improvements 1987"

Stanley Associates, 1988

Memo: Mayo Warm Water Well, File: 49-67-1-2, 15 April, 1988

Stanley Associates, 1987

"Village of Mayo Proposal Water Source District Heat Pump System" dated March 1987

Stanley Associates, 1983

"Proposal for Mayo Local Improvement District Geothermal Heating Study"

Village of Mayo, 2001

"Village of Mayo Annual Water License Report, 2001"

Village of Mayo, 2000

"Village of Mayo Annual Water License Report, 2000"

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited (NovaTec), 2002

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities, Final Report, Na'cho N'yak Dun First Nation"

Gartner Lee Limited, 2003

"Rehabilitation Assessment of Mayo Warm Water Well No. 1" for the Village of Mayo, Gartner Lee project no. 22-294 dated March 2003

5.12 Old Crow

Government of Yukon (YTG), 2000a

"Water Use License MN95-003", Old Crow Sewage Lagoon, 1998 Report and 1999 Report

Government of Yukon (YTG), 2000b

"Yukon Statistical Review – 2000 Annual Report", YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

"Community Profiles", YTG Community and Transportation Services document dated May 15, 1991.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory". January 1975.

Gartner Lee Limited, G.J. Bull & Associates Inc. (BA), Access Consulting Group, NovaTec Consulting Limited (NovaTec), 2002

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities, Final Report, Vuntut Gwitchin First Nation"

Stanley Associates Engineering Ltd. (Stanley Associates) 1979:

"Old Crow Water Supply Study" for YTG, November 1979.

EBA Engineering Consultants, Ltd. (EBA), 1982

"Old Crow Groundwater Supply, A Geotechnical Hydrological and Thermal Study, Old Crow, Yukon" dated July 1982

Groundwater Database, Data Input Form

5.13 Pelly Crossing

EBA Engineering Consultants Ltd. (EBA), 1997:

"Community Water and Sewer Planning Study, Pelly Crossing, Y.T.", report for Selkirk First Nation dated November 1997.

Gartner Lee Limited (Gartner Lee) and G.J. Bull & Associates Inc. (BA), 2002:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Selkirk First Nation", report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Hydrogeological Consultants Ltd. (HCL), 1996:

"Selkirk First Nation, Pelly Crossing Truck Fill Station Water Well Testing, 419400 Easting,

6967600 Northing, Zone 08, NAD27, Water Well Evaluation", report for Selkirk first Nation dated October 1996.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Klohn Leonoff Yukon Ltd. (KLYL), 1988:

"Site Investigation For Sewage Disposal and Water Supply, Pelly Crossing", report for Yukon Department of Community and Transportation Services dated February 19, 1988.

Lorimer & Associates (Lorimer), 1995:

"1994 Assessment of Water Supply and Sewage Disposal Systems in Pelly Crossing", report for Selkirk First Nation dated March 6, 1995 (Lorimer project no. YT 140.01).

Midnight Sun Drilling Co. Ltd. (Midnight Sun), 1988:

Drill logs for various locations in Pelly Crossing, Yukon, including House Nos. 1, 16, 19, 25, 26, 27, 31, 39, 45, 49, 61, lot 16, new fire hall and community hall, installed during September 1988

Piteau Engineering Ltd. (Piteau) and Integrated Environments, 1989:

"Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

Yukon Community Profiles (YCP). 2002:

"The Community of Pelly Crossing", <http://www.yukoncommunities.yk.ca/watson.html> (November 27, 2002).

Yukon MINFILE, 2001:

"Mineral Occurrence Map 115I", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

Whitewater Resources (Whitewater), 2001:

Drill logs for locations in Pelly Crossing, Yukon, including those identified as *"campsite, west side of highway"* and *"duplex by Band office"*, dated June 19 2001 and June 25, 2001, respectively.

5.14 Ross River

Access Consulting Group and G.J. Bull & Associates Inc. (BA), 2002:

"Application for Type 'A' Water Use License Renewal, Village of Ross River, Municipal Water Supply and Waste Water Treatment & Disposal Facility", report for Yukon Government, Community Services, Community Development Branch dated June 2002 (Application MN02-044).

Yukon Groundwater and Ground Source Heat Potential Inventory

- David Nairne & Associates Ltd. (DNAL) and NovaTec Consulting Limited (NovaTec), 1990:
"Ross River Sewage Collection, Treatment and Disposal Pre-Design", DNAL project no. 2064 dated March 1990.
- Gartner Lee Limited (Gartner Lee) and G.J. Bull & Associates Inc. (BA), 2002:
"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Ross River Dena First Nation", report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).
- Government of Yukon (YTG), 2000:
"Yukon Statistical Review – 2000 Annual Report", YTG Executive Council Office, Bureau of Statistics dated December 2000.
- Government of Yukon (YTG), 1991
"Community Profiles", YTG Community and Transportation Services document dated May 15, 1991.
- Hoggan Engineering & Testing (1980) Ltd., 1989:
"Geotechnical Investigation 1989/11/09, Ross River Roads and Sanitary Sewer Development, Ross River, Yukon Territory", report for YTG, Community and Transportation Services dated November 9, 1989.
- Interra Environmental Consultants Ltd. (Interra), 1975:
"Groundwater Management Study of the Yukon Territory", report dated January 1975.
- Stanley Associates Engineering Ltd. (Stanley Associates), 1986:
"Groundwater Supply Investigation", report for Yukon Territorial Government, Community and Transportation Services dated November 4, 1986.
- Synergy West Ltd. (Synergy West), 1975
"A Community Development Plan for Ross River, Y.T.", report for Department of Local Government of YTG and the Community of Ross River, April 1975.
- Underwood McLellan (1977) Ltd. (Underwood), 1978
"Pre Design Report on Sewer and Water Utilities for Ross River, Y.T.", report for YTG and the Community of Ross River, Final Report dated December 1978.
- Yukon MINFILE, 2001:
"Mineral Occurrence Map 105F", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5.15 Teslin

Gartner Lee Limited (Gartner Lee) and G.J. Bull & Associates Inc. (BA), 2002:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Teslin Tlingit First Nation", report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).

Government of Yukon (YTG), 2000:

"Yukon Statistical Review – 2000 Annual Report", report to YTG Executive Council Office, Bureau of Statistics dated December 2000.

Government of Yukon (YTG), 1991

"Community Profiles", YTG Community and Transportation Services document dated May 15, 1991.

Hydrogeological Consultants Ltd. (HCL), 1987:

"Yukon Territorial Government, Community and Transportation Services, Community of Teslin, 1987 Water Well", report dated February 1987.

HCL, 1974:

"A Review of Groundwater Data, Teslin, Y.T.", report dated February 16, 1974.

Klohn Leonoff (KL), 1987:

"Terrain Suitability Study, Teslin and Vicinity, Yukon Territory", report for Yukon Community and Transportation Services dated April 6, 1987 (KL project number PB3744-0103).

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Piteau Engineering Ltd. (Piteau) and Integrated Environments, 1989:

"Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

Stanley Associates Engineering Ltd. (Stanley Associates), 1981:

"Teslin Water Supply and Distribution System", report to YTG dated June 26, 1981, Stanley Associates project no. 1060-25-1-1.

Stanley Associates, 1980:

"Groundwater Supply, Teslin, Yukon Territory", report dated June 1980

Yukon Community Profiles (YCP). 2002:

"The Community of Watson Lake", <http://www.yukoncommunities.yk.ca/watson.html> (November 27, 2002).

Yukon MINFILE, 2001:

"Mineral Occurrence Map 105C", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

5.16 Watson Lake

EBA Engineering Consultants Ltd. (EBA), 1981a:

"Geotechnical Evaluation for Campbell Subdivision, Watson Lake Wye", report for Stanley Associates Engineering Ltd., dated November 1977.

EPEC Consulting Western Ltd. (EPEC), 1980:

"Liard Indian Band, Feasibility and Conceptual Design Studies on Water and Sewage Systems For: Upper Liard Village, 2 Mile Village, 2 - 1/2 Mile Village and Lower Post Village" report dated March 1980.

Gartner Lee Limited (Gartner Lee) and G.J. Bull & Associates Inc. (BA), 2002:

"Assessment Study of Water and Wastewater Systems and Associated Water Management Practices in Yukon Region First Nation Communities - Final Report, Liard First Nation" report for Taku River Tlingit First Nation dated February 2002 (Gartner Lee project no. 21-939).

J. Gibson Environmental Consulting (Gibson) (2000):

"2000 Annual Water Use Report for Town of Watson Lake, Yukon - Water Use License MN95-001", report for Town of Watson Lake dated December 2000.

J. Gibson Environmental Consulting (Gibson) (1997):

"1996 Annual Water Use Report for Town of Watson Lake, Yukon Territory (MN95-001)", report for Town of Watson Lake dated December 2000.

Government of Yukon (YTG), 2000

Yukon Statistical Review – 2000 Annual Report, YTG Executive Council Office, Bureau of Statistics, December 2000.

Government of Yukon (YTG), 1991

Community Profiles, YTG Community and Transportation Services document dated May 15, 1991.

Hydrogeological Consultants Ltd. (HGL), 1996:

"Town of Watson Lake, Bellevue Subdivision - Phase II 1996 Groundwater Program", report for YTG dated November 1996.

Intera Environmental Consultants Ltd. (Intera), 1975:

"Groundwater Management Study of the Yukon Territory", report dated January 1975.

Klassen, R.W., and S.R. Morison. 1981:

"Surficial Geology Watson Lake, Yukon Territory", Geological Survey of Canada Map 21-1981, scale 1:250,000.

Piteau Engineering Ltd. (Piteau) and Integrated Environments, 1989:

"Report to Indian and Northern Affairs Canada on Groundwater Database for the Yukon", report for Indian and Northern Affairs Canada dated March 1989 (Piteau project no. A88-2298).

Stanley Associates Engineering Ltd. (Stanley Associates), 1977:

"*Watson Lake L.I.D. Standby Water Well*", report for Yukon Territory Government dated June 23, 1977 (Stanley Associates project no. 1060-11-1-2).

Stanley Associates, 1980:

"*Watson Lake, Industrial Subdivision Phase II*", report for YTG, Department of Municipal and Community Affairs.

Stanley Associates, 1984:

"*Effects of Lake Level Decline on Water Supply Wells*", draft report for Town of Watson Lake dated October 1984.

Stanley Associates, 1985:

"*Effects of Lake Level Decline on Water Supply Wells*", draft report for Town of Watson Lake dated January 1985.

Yukon Community Profiles (YCP). 2002:

"*The Community of Watson Lake*", <http://www.yukoncommunities.yk.ca/watson.html> (November 27, 2002).

Yukon MINFILE, 2001:

"*Mineral Occurrence Map 105A*", scale 1:250,000, Exploration and Geological Services Division, Yukon, Indian and Northern Affairs Canada.

UMA Engineering Ltd. (UMA), 1988:

"*Infrastructure Study, Water and Sewage System, Upper Liard, Yukon*", report dated March 1988 (UMA project no. 1539-059-00-02).

5.17 Whitehorse

Gartner Lee Limited (Gartner Lee), 1999:

"*1997 Warm Water Well Development Program*" for City of Whitehorse, Gartner Lee project no. 97-773.

Gartner Lee, 2000a:

"*1999 Warm Water Well Rehabilitation Program*" for Aqua Tech Supplies & Services, Gartner Lee project no. 99-924.

Gartner Lee, 2000b:

"*Hydrogeological Assessment of the Spruce Hill Subdivision*" for Government of Yukon, Community & Transportation Services, Gartner Lee project no. 99-926.

Yukon Groundwater and Ground Source Heat Potential Inventory

Gartner Lee, 2001b:

"Wolf Creek/Pineridge Subdivisions Groundwater Usage Study" for Government of Yukon, Engineering & Development Branch, Gartner Lee project no. 20-924.

Gartner Lee, 2001c:

"2000 Warm Water Well No. 6 Rehabilitation Program" for Aqua Tech Supplies & Services. Gartner Lee project no. 20-924.

Gartner Lee, 2002a:

Letter report regarding *"Demonstration Borehole and Vertical Ground Loop Installation, Whitehorse Honda Dealership"* for Energy Solutions Centre Inc., Gartner Lee project no. 22-433.

Gartner Lee, 2003:

"Preliminary Groundwater Inventory of the City of Whitehorse" for Government of Yukon, community & Transportation Services, Gartner Lee project no. 21-913.

Gartner Lee, 2003b:

"Vanier School Ground Source Heat Pump Project – Hydrogeological Assessment" for Energy Solutions Centre Inc., Gartner lee project no. 22-292

Gartner Lee, 2003c:

Letter report regarding *"Versluc Spring Site Visit and Water Quality Testing"* for City of Whitehorse, Engineering & Environmental Services, Gartner Lee project 23-299.

Gartner Lee, 2003d:

"Wolf Creek and Pineridge Subdivisions Groundwater Quality Assessment" for City of Whitehorse. Whitehorse, Yukon,

Hydrogeological Consultants Limited (HCL), 1976:

"City of Whitehorse 1976 Warm Groundwater Exploration Program" for City of Whitehorse.

HCL, 1990a:

"Granger Subdivision – City of Whitehorse, Hillcrest Reservoir Test Well, Aquifer Test Analysis. File No. 90-160" for Government of Yukon, Department of Community and Transportation Services.

HCL, 1990b:

"City of Whitehorse, Hillcrest/Valleyview Subdivisions 1990 Groundwater Test-Drilling Program. Water Test Hole No. 2-90. File No. 90-162" for Government of Yukon, Department of Community and Transportation Services.

HCL, 1995:

"Proposed Cowley Creek II Subdivision. UTM Zone 8, NTS Map Sheets 105D/10 and 11. Water Test Hole No. 1-95", for Lorimer & Associates.

Yukon Groundwater and Ground Source Heat Potential Inventory

Kala Groundwater Consulting Ltd., 1986:

"Whitehorse Fish Hatchery, Groundwater Development Program" for Department of Fisheries and Oceans.

Mougeot GeoAnalysis and Agriculture and Agri-Food Canada, 1997:

"Soil, Terrain and Wetland Survey of the City of Whitehorse", Draft Report with Maps at 1:20,000 scale, for the City of Whitehorse.

Stanley Associates Engineering Limited (Stanley Associates), 1980:

"1979 Groundwater Exploration Program, Selkirk Area" for the City of Whitehorse.

Stanley Associates, 1981:

"1980 Groundwater Exploration Program, Whitehorse Aquifer" for the City of Whitehorse..

Thompson Geotechnical Consultants Ltd., 1984:

"Geotechnical Studies Mary Lake Subdivision" for Underhill Engineering Ltd.

UMA Engineering Limited, 2001:

"A Planning Foundation and Vision for the City of Whitehorse, City of Whitehorse Official Community Plan" for the City of Whitehorse.

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Yukon Groundwater and Ground Source Heat Potential Inventory

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Appendices

Appendix A

Community Profiles

Appendix A

Simplified Community Profiles

Beaver Creek Community Information

Table 1. Geographic and Demographic Information for Beaver Creek

Latitude	62° 25'
Longitude	140° 52'
UTM zone	zone 7
UTM Grid Northing	6,916,740
UTM Grid Easting	506,440
Elevation	649 m amsl
Population ^a (2001)	88
Private Dwellings (2001) ^a	58

^a Statistics Canada (2001)

- Macauley Ridge is 6.5 km east, elevation 3,500 ft (1,066 m) amsl
- Beaver Creek is 2 km east, elevation 2,140 ft (652 m) amsl

Most Beaver Creek Community Services:

- Mile 1202 Motel;
- The Beaver Creek School;
- Ida's Motel and Restaurant;
- Skating/Curling rink (seasonal);
- Canada Customs office;
- Indoor swimming pool;
- Community Library;
- Royal Canadian Mounted Police (RCMP) detachment;
- Canada Post (part-time office);
- Three service stations;
- Airport; and
- White River First Nation Band Office.

Burwash Landing Community Information

Table 2. Geographic and Demographic Information for Burwash Landing

Latitude	61° 21' 15"
Longitude	138° 59' 40"
UTM zone	Zone 7
UTM Grid Northing	6,803,820
UTM Grid Easting	607,430
Elevation	800 m amsl
Population ^a (2001)	88
Private Dwellings (2001) ^a	58

^a Statistics Canada (2001)

- Elevation Kluane Lake: 777 m (2,550 feet) amsl;

Most Community Services in Burwash Landing:

- Kluane First Nation Band Office;
- Kluane First Nation Nursing Station;
- Kluane First Nation wash house;
- Fire hall;
- Community Centre (recreation hall, skating rink);
- Museum (seasonal);
- Service station (seasonal);
- Airport; and
- Burwash Landing Resort (seasonal).

Destruction Bay Community Information

Table 3. Geographic and Demographic Information for Destruction Bay

Latitude	61° 15' 15"
Longitude	138° 48' 25"
UTM zone	Zone 7
UTM Grid Northing	6,792,640
UTM Grid Easting	618, 170
Elevation	793 m
Population ^a (2001)	43
Private Dwellings ^a (2001)	20

^a Statistics Canada (2001)

Most Common Community Services in Destruction Bay

- Community Hall;
- Municipal Works Yard;
- Destruction Bay School (grades kindergarten through grade 8);
- Destruction Bay Nursing Station; and
- Talbot Arms Hotel/Restaurant and service station.

Haines Junction Community Information

Table 4. Geographic and Demographic Information for Haines Junction

Latitude	60° 45' 10"
Longitude	137° 30' 25"
UTM zone	zone 8
UTM Grid Northing	6,737,870
UTM Grid Easting	363,300
Elevation	701 m amsl
Population	n/a
Private Dwellings	n/a

- Elevation of Mt. Worthington (approximately 30 km south of Haines Junction): 2,175 m (7,113 feet) amsl

Most Common Community Services in Haines Junction

- Municipal Hall;
- Municipal Works Yard;
- St. Elias Community School (grades kindergarten through grade 12);
- Health Care Centre;
- Champagne Aishihik First Nation Band Office;
- RCMP detachment;
- Swimming pool;
- Library;
- Fuel outlets (9);
- Commercial Recreational Vehicle sites (6);
- Arena;
- Health centre;
- Four-season motels/hotels (6);
- Seasonal motel/hotels (3);
- Restaurants (6);
- Bakery/deli;
- General store;
- Retail outlet stores; and
- Airport.

Geographic Information for Mayo

Table 5. Geographic and Demographic Information for Town of Mayo

Latitude	63° 35' 35"
Longitude	135° 53' 54"
UTM zone	8
UTM Grid Northing	7,052,670
UTM Grid Easting	455,930
Elevation	487 m amsl
Population ^a (2001)	366
Private Dwellings (2001) ^a	191

^a Statistics Canada (2001)

Most Common Community Services in Mayo

- Municipal Hall;
- Municipal Works Yard;
- J.V. Clark School (grades kindergarten through grade 12 and Mayo campus of Yukon College);
- Mayo Nursing Station;
- Renewable Resources Building;
- Government of Yukon (YTG) Administration Building (library, post office);
- Airport;
- Na-Cho Ny'a'k Dun First Nation Band Office;
- Swimming pool;
- Curling Rink;
- RCMP detachment;
- Bedrock Motel;
- North Star Motel;
- Laundromat;
- Grocery store;
- Fire Hall;
- Restaurant;
- Silver Trail Café and Service Station; and
- Second service station.

Geographic Information for Keno

Table 6. Geographic and Demographic Information for Town of Keno

Latitude	63° 54' 30"
Longitude	135° 18' 10"
UTM zone	8
UTM Grid Northing	7,086,780
UTM Grid Easting	485,200
Elevation	930m amsl
Population ^a (2001)	Approximately 10 to 25
Private Dwellings	n/a

^a Statistics Canada (2001)

- Elevation of Monument Hill (approximately 4 km northeast of Keno): 1,849 m (6,065 feet) amsl;
- Elevation of Sourdough Hill (approximately 700 m south of Keno): 1,445 m (4,739 feet) amsl; and
- Elevation of Galena Hill (approximately 2 km east of Keno): 1,445 m (4,740 feet) amsl.

Most Common Community Services in Keno

- Fire Hall;
- Municipal Works Yard;
- Keno Hotel/Cafe; and
- Keno Mining museum.

Geographic Coordinates of Dawson

Table 7. Geographic and Demographic Information for City of Dawson

Latitude	64° 03' 45"
Longitude	139° 25' 50"
UTM zone	zone 7
UTM Grid Northing	7,104,670
UTM Grid Easting	576,690
Elevation	97 m amsl
Population ^a (2001)	1251
Private Dwellings (2001) ^a	675

^a Statistics Canada (2001)

- Elevation of Midnight Dome (immediately east of Dawson): 268 m (880 feet) amsl.

Most Common Community Services in Dawson

- Municipal Hall;
- Municipal Works Yard;
- Robert Service School (kindergarten to grade 12);
- Service Stations (Shell and Esso);
- Recreational Centre;
- Indoor ice arena;
- Community Health Centre;
- RCMP detachment;
- Dawson City Fire Hall;
- YTG administrative building;
- Bank;
- Retail stores;
- Churches;
- Hotels;
- Restaurants/Lounges;
- Theater and Meeting Halls;
- Airport;
- Grocery stores; and
- RV parks.

Geographic Coordinates of Old Crow

Table 8. Geographic and Demographic Information for Old Crow

Latitude	67° 34' 05"
Longitude	139° 50' 0"
UTM zone	7
UTM Grid Northing	7, 495, 260
UTM Grid Easting	549, 480
Elevation	259 m amsl
Population (1998)	292
Private Dwellings (2001)	n/a

Most Common Community Services in Old Crow

- Community hall;
- Cooperative store;
- Post office;
- YTG garage;
- RCMP detachment;
- Nursing Station;
- Chief Zzeh Gittlit School;
- Vuntut Gwitchin First Nation Band Office; and
- Airstrip.

Geographic Coordinates of Carcross

Table 9. Geographic and Demographic Information for Carcross

Latitude	60° 10' 00"
Longitude	134° 42' 00"
UTM zone	8
UTM Grid Northing	6,669,870
UTM Grid Easting	516,280
Elevation	approximately 660 m amsl
Population (2003)	394
Private Dwellings (2001)	n/a

- Elevations of Bennett and Nares Lakes: approximately 655 m amsl; and
- Elevation of Nares Mountain (approximately 7 km east of Carcross): approximately 1,642 m amsl.

Most Common Community Services in Carcross

- The White Pass & Yukon Railway Station and Visitors Centre;
- Library;
- Health Centre;
- Carcross School (kindergarten through grade 9);
- Recreation Centre;
- Museum;
- Curling and skating rinks;
- Community pool (seasonal);
- Carcross campus of Yukon College;
- Caribou Hotel;
- Airstrip (four-season 2,800 foot gravel runway without fuelling facilities);
- YTG highway maintenance garage;
- Service station;
- RCMP detachment; and
- Fire Department.

Geographic Coordinates of Carmacks

Table 10. Geographic and Demographic Information for Carmacks

Latitude	62° 05' 20"
Longitude	136° 17' 20"
UTM zone	8
UTM Grid Northing	6884800
UTM Grid Easting	432820
Elevation	525m amsl
Population (2003)	407
Private Dwellings (2001)	n/a

- Elevation of the Yukon River near Carmacks: approximately 518 m amsl and
- Elevation of Tantalus Butte (located approximately 4 km north northeast of Carmacks): 782 m amsl.

Most Common Community Services in Carmacks

- Village Municipal Building;
- Tantalus School (kindergarten through grade 12);
- Carmacks campus of Yukon College;
- Curling rink;
- Recreation complex;
- Swimming pool (seasonal);
- Health Centre
- RCMP detachment;
- Volunteer Fire Department;
- Library;
- First Nations Interpretive Centre;
- Hotel/restaurant/general store complex;
- YTG highway maintenance garage;
- YTG Lands and Forest Services facility; and
- A 5,200 foot gravel airstrip (located approximately 12 km north of Carmacks adjacent to the Robert Campbell Highway).

Geographic Coordinates of Faro

Table 11. Geographic and Demographic Information for Faro

Latitude	62° 13' 50.3"
Longitude	133° 21' 0.7"
UTM zone	8
UTM Grid Northing	6900610
UTM Grid Easting	585750
Elevation	701 m amsl
Population (2003)	363
Private Dwellings (2001)	n/a

- Elevation of Mt. Mye (approximately 1,600 m northeast of Faro): 2,061 m (6,763 feet) amsl and
- Elevation of the Pelly River approximately 700 m southwest of Faro): 640 m (2,101 feet) amsl.

Most Common Community Services in Faro

- Municipal Hall;
- Municipal works yard;
- Del Van Gorder School (grades kindergarten through grade 12);
- Faro campus of the Yukon College;
- Faro Nursing Station;
- Union hall;
- YTG Health and Social Services;
- Recreation centre (including gymnasium, seasonal swimming pool, seasonal curling rink, squash court, youth centre);
- Indoor ice arena;
- Library;
- RCMP detachment;
- Canada Post (full-service post office);
- Retail mall;
- Churches (2);
- Hotel/restaurant facility;
- Service station; and
- Airport (4,000 foot gravel runway with lights)

Geographic Coordinates of Pelly Crossing

Table 12. Geographic and Demographic Information for Pelly Crossing

Latitude	62° 49' 05"
Longitude	136° 34' 10"
UTM zone	8
UTM Grid Northing	6967090
UTM Grid Easting	419730
Elevation	461 m amsl
Population ^a (2001)	328
Private Dwellings ^a (2001)	124

^a Statistics Canada (2001)

- Elevation of Pelly River near Pelly Crossing: 460 m (1,505 feet) amsl.

Most Common Community Services Pelly Crossing

- Community Hall (Selkirk First nation Administration Building);
- Eliza Van Bibber School (grades kindergarten through Grade 12);
- Pelly Crossing campus of Yukon College;
- Youth Centre;
- Arena/curling rink;
- Health Centre;
- RCMP detachment;
- Fire Department;
- Museum; and
- Card-lock service station..

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Geographic Coordinates of Ross River

Table 13. Geographic and Demographic Information for Ross River

Latitude	61° 59' 2.2"
Longitude	132° 26' 46.3"
UTM zone	8
UTM Grid Northing	6874750
UTM Grid Easting	633750
Elevation	693 m amsl
Population (2003)	329
Private Dwellings (2001)	n/a

- Elevation of the Pelly River at Ross River: 690 m amsl; and
- Mt. Green (located approximately 30 km south of Ross River): 2,033 m amsl.

Most Common Community Services Ross River

- YTG highway maintenance yard;
- Ross River School (grades kindergarten through grade 10);
- Ross River campus of the Yukon College;
- Ross River Nursing Station;
- YTG Forestry Services Station;
- Recreation complex (including an arena, Community Hall and library);
- curling Rink;
- RCMP detachment;
- Canada Post (full-service post office);
- Churches (1);
- Service station (1; in 1975, a gasoline dispenser was also located at the general store); and
- Airstrip (5,500 foot gravel runway with lights).

Geographic Coordinates of Teslin

Table 14. Geographic and Demographic Information for Teslin

Latitude	60° 10' 00"
Longitude	132° 43' 15"
UTM zone	8
UTM Grid Northing	6672110
UTM Grid Easting	626640
Elevation	684 m amsl
Population (2003)	396
Private Dwellings (2001)	n/a

- Elevation of Teslin Lake is approximately 682 m amsl; and
- Elevations of the Pelly Mountains (located within the Big Salmon Range), approximately 3 km north of Teslin, range between approximately 944 m and 1,380 m amsl.

Most Common Community Services in Teslin

- Teslin Tlingit Council Administration Building (in Smarchville, just west of the Main Community);
- Teslin School (grades kindergarten through Grade 9);
- Teslin campus of Yukon College (located within the Teslin Tlingit Council Administration Building);
- Health Centre;
- RCMP detachment;
- Fire Department;
- Recreation complex and curling rink;
- Library;
- George Johnston Museum (seasonal); and
- Airstrip.

Geographic Coordinates of Watson Lake

Table 15. Geographic and Demographic Information for Watson Lake

Latitude	60° 03' 50"
Longitude	128° 42' 20"
UTM zone	9
UTM Grid Northing	6658350
UTM Grid Easting	516430
Elevation	700 m amsl
Population (2003)	1554
Private Dwellings (2001)	n/a

- Elevation of Watson Lake (eponymous water body) located 3 km northwest of the Town of Watson Lake is approximately 680 m amsl; and
- the Liard River is approximately 4 km south of Watson Lake at an approximate elevation of 600 m amsl.

Most Common Community Services in Watson Lake

- Municipal Hall and Watson Lake Public Library Complex;
- Municipal works yard;
- Elementary and secondary schools;
- Watson Lake campus of the Yukon College;
- Medical clinic;
- Watson Lake Hospital (including public health services);
- RCMP detachment;
- Fire Department;
- Post Office;
- Grocery and department stores;
- Service stations, fuel oil and propane suppliers;
- Retail strip mall;
- Multiple four-season hotels and motels and dining establishments;
- The Northern Lights Centre (a tourist and presentation centre); and
- Airport (located approximately 13 km north of town).

Appendix B

Water Well Database Documentation

Water Well Database Documentation

The digital Yukon Territory water well database created for this project is found on the accompanying CD-ROM and entitled **YTGW.mdb**, located in the /database directory of the CD-ROM. The database is created using Microsoft Access 97.

1.1 Data Model

Water well database development for this project is an expansion of a "flat" water well database that Gartner Lee developed for the Wolf Creek-Pineridge area (Gartner Lee 2001) to a fully relational database. This allows unlimited expandability to the database and significant flexibility. An orthogonal data model is used that allows one-to-many relationships. The database structure is illustrated in Figure B1.

The data model that was used for this project is widely used in Canadian well databases and is similar to the existing B.C. and Ontario provincial water well databases. This data design follows the EarthFX data model that is currently used for most of the Ontario Oak Ridges Moraine hydrogeological assessment projects. The database design is also consistent with the Federal Provincial Groundwater Working Group's Guidelines for Groundwater Data Management (1991). However, the proposed scope and extent of the database is significantly simpler and more limited than the above-mentioned databases. Because the database is open and flexible, the database lends itself to increased complexity over time, as needed.

1.2 Database Tables

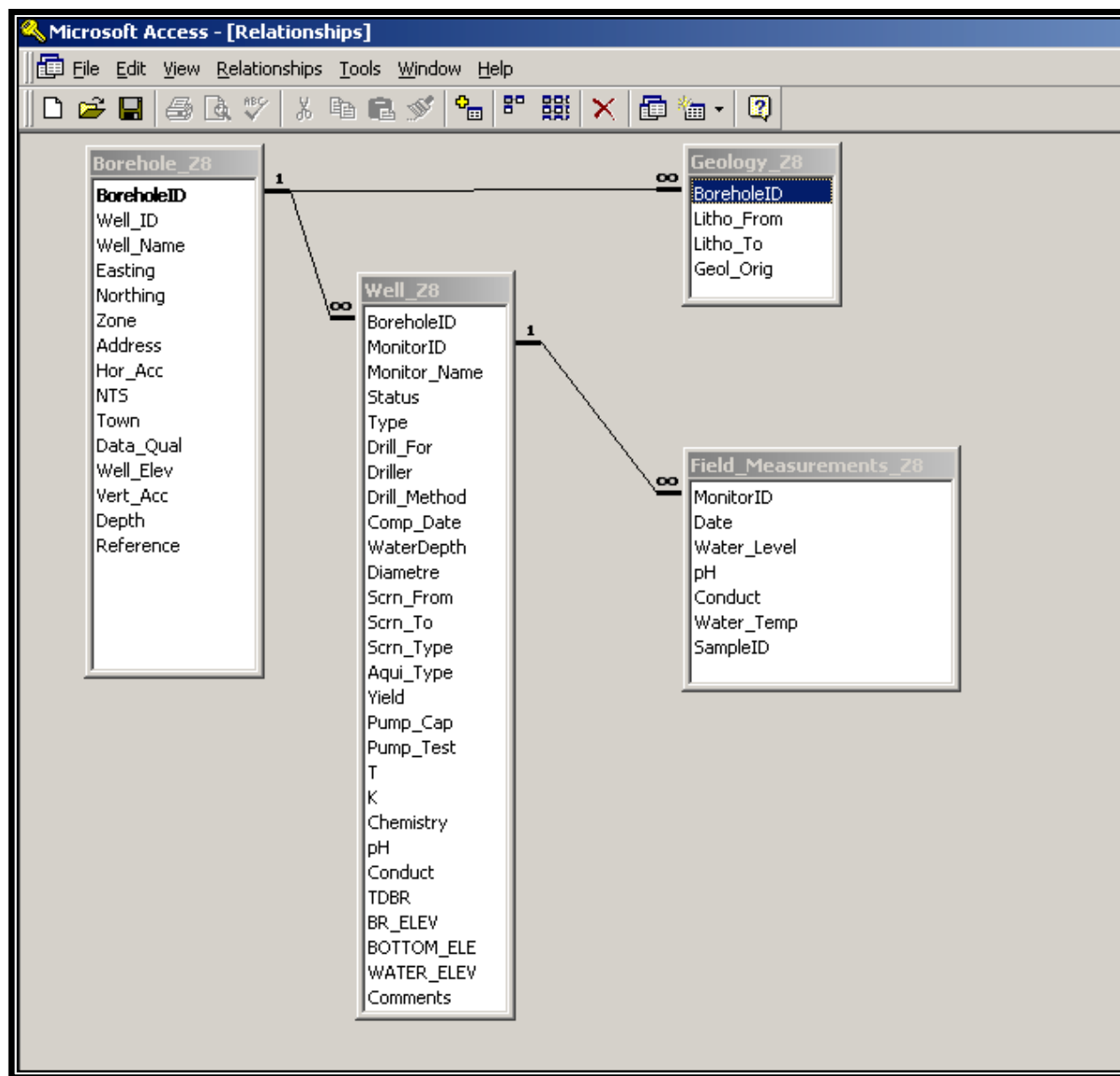
This database structure consists of four primary tables:

1. **Borehole** – A borehole location table, each location receives a unique identifier (BoreholeID) in this primary table.
2. **Well** – Well construction, usage and other aquifer details. A one-to-many relationship with the Borehole table (via the BoreholeID) allows multiple wells per borehole. Multiple level monitoring wells are frequently used in environmental investigations.
3. **Geology** – Stratigraphic information encountered during borehole drilling. The one-to-many relationship with the Borehole table (via the BoreholeID) allows unlimited Stratigraphic intervals at each.



Water Well Database Documentation

Figure B1. Water Well Database Model



Water Well Database Documentation

4. **Field_Measurements** – Basic field measurement data include water level and groundwater temperature data. A one-to-many relationship with the Well table (via the MonitorID) allows multiple measurements over time (e.g., changes in water temperature or level over multiple years).

The database includes ancillary tables used for report references and look-up tables to standardize data entry.

Ancillary tables include:

- **R_Data_Qual_Code** – Reference table for data quality codes. Use for data lookup in Borehole table.
- **R_Drill_Method** – Reference table for drilling method codes. Use for data lookup in Well table.
- **R_Driller** – Reference table for drilling company codes. Use for data lookup in Well table.
- **R_Hor_acc** – Reference table for horizontal location accuracy codes. Use for data lookup in Borehole table.
- **R_Town** – Reference table for town/community codes. Use for data lookup in Borehole table.
- **R_Vert_acc** – Reference table for vertical location accuracy codes. Use for data lookup in Borehole table.
- **R_Well_Status** – Reference table for well status codes. Use for data lookup in Well table.
- **R_Well_Type** – Reference table for well type codes. Use for data lookup in Well table.
- **References** – Report and data source references (bibliography). Use for data lookup in Borehole table.

The database is fully documented and commented internally. Complete database documentation is found at the end of this Appendix. All borehole data is referenced by UTM (NAD83) co-ordinates. The UTM coordinate system is used for the following reasons:

- it is metres-based (rather than being based on degrees of longitude and latitude, which are not readily measurable on the ground);
- most hand-held GPS units can identify UTM co-ordinates; and
- site-specific maps produced in the UTM system have minimal associated distortion.

As with any digital data, the concept of “garbage-in, garbage-out” applies. Some of the digital data QA/QC measures that have been incorporated into the database include:

- extensive use of data-validation rules, mandatory data fields, and code tables during data entry; and
- use of data-quality terms, including provision of general data completeness fields and mandatory horizontal and vertical accuracy codes.

Water Well Database Documentation

1.3 Database Fields

Primary database tables and fields are as follows. Reference tables provide a summary of database codes used.

Table B1 Borehole Table Fields

Field	Description	Reference (Lookup) Table
Well Name	Local, or recent reference name of well	
BoreholeID	Unique borehole identifier (see discussion of BoreholeID numbering system below)	
Easting	UTM Easting Coordinate (NAD83)	
Northing	UTM Northing Coordinate (NAD83)	
Well Elev	Well head elevation (m ASL)	
Depth	Total <i>borehole</i> depth (in metres)	
Hor_acc	Horizontal accuracy code	R_Hor_acc
Vert_acc	Vertical (elevation) accuracy code	R_Vert_Acc
OldWell_ID	Old well ID from previous reports/databases	
UTMZone	UTM Zone (zone 7-10 for Yukon)	
Address	General street address	
NTS	1:50,000 NTS topographic mapsheet number	
Town	Name of town or community well is located in.	R_Town
Data_Qual	Data quality / completeness field (good, fair, or poor)	R_Data_Qual
Type	Purpose of well	R_Type
Drill_For	Person or agency well was drilled for	
Driller	Drilling company code	R_Driller
Comp_Date	Well completion data completion date of deepening	
Reference	Report reference/data source	R_Reference

Appendix B

Water Well Database Documentation

Table B2 Well Table Fields

Field	Description	Reference (Lookup) Table
Borehole ID	Links well to borehole table	
MonitorID	Unique well (monitor) identify	
Monitor_Name	Name of well or monitor (allows unique names for multiple monitors per location)	
WaterDepth	Initial depth to static water level (in meters from top of pipe/casing)	
Diameter	Well diameter (in centimeters)	
Scrn From	Depth to top of screen (in metres)	
Scrn To	Depth to bottom of screen (in metres)	
Scrn type	General description of well screen type	
Yield	Estimate of well yield (in L/s) – either calculated long-term yield from pumping test or driller's estimate	
Status	Usage status of well	R_Status
Pump_cap	Installed pump capacity (in L/s)	
Pump Test	Date of pump test (if conducted)	
T	Reported transmissivity (m ² /day) – use best value if multiple estimates	
K	Reported hydraulic conductivity (m/s) – use best or mean value if multiple estimates.	
Chemistry	Chemical analysis available? (Yes/No)	
pH	Initial reported water pH	
Conduct	Initial reported water electrical conductivity (µmhos/cm)	
Comments	Misc. comments for other notes	

Table B3 Geology Table Fields

Field	Description	Reference (Lookup) Table
BoreholeID	Links well to Borehole table	
Litho From	Depth from surface to top of lithologic interval	
Litho To	Depth from surface to bottom of lithologic interval	
Geol Orig	Geological material description as originally reported in drilling record	

Water Well Database Documentation

Table B4 Field_Measurements Table Fields

Field	Description	Reference (Lookup) Table
Monitor ID	Links measurement to Well table	
SampleID	Identifier assigned to water sample, if collected	
Date	Date of field measurement	
Water_Level	Depth to water (m below top of casing)	
Stickup	Height above ground of riser pipe (or inner casing), in metres (this may change overtime if well is damaged)	
pH	Field measurement of water pH	
Conduct	Field measurement of water electrical conductivity (umhos/cm)	
Water_Temp	Field measurement of groundwater temperature (degrees Celsius)	
Hardness	Field Measurement of groundwater hardness (mg/L as CaCO3)	
Comments	Physical Description of sample including odour, colour etc.	

1.4 BoreholeID Numbering System

The BoreholeID is a unique number assigned to every borehole. This number allows wells and/or monitor construction details, geology and water chemistry to all be linked to a unique borehole. The boreholeID consists of unique 9 digit number where the first 5 numbers represent the 1:50,000 scale NTS mapsheet and the last 4 digits represents a unique borehole number within that mapsheet, numbered sequentially from 1 to 9999. This allows up to 10000 borehole per 1:50,000 scale NTS mapsheet area.

The NTS numbering prefix component of the BoreholeID is as follows, Figure B2 illustrates the NTS mapsheet number prefix areas.

1. The first digit represents the 1:500,000 scale mapsheet number:
 - 1 – 115
 - 2 – 105
 - 7 – 106
 - 8 – 116
 - 9 – 117
2. The second and third digits represents the 1:250,000 scale NTS mapsheet letter (as illustrated in B1)
3. The forth and fifth digits represent the 1:50,000 scale NTS mapsheet number (ranging from 01 to 16)



Appendix B

Water Well Database Documentation

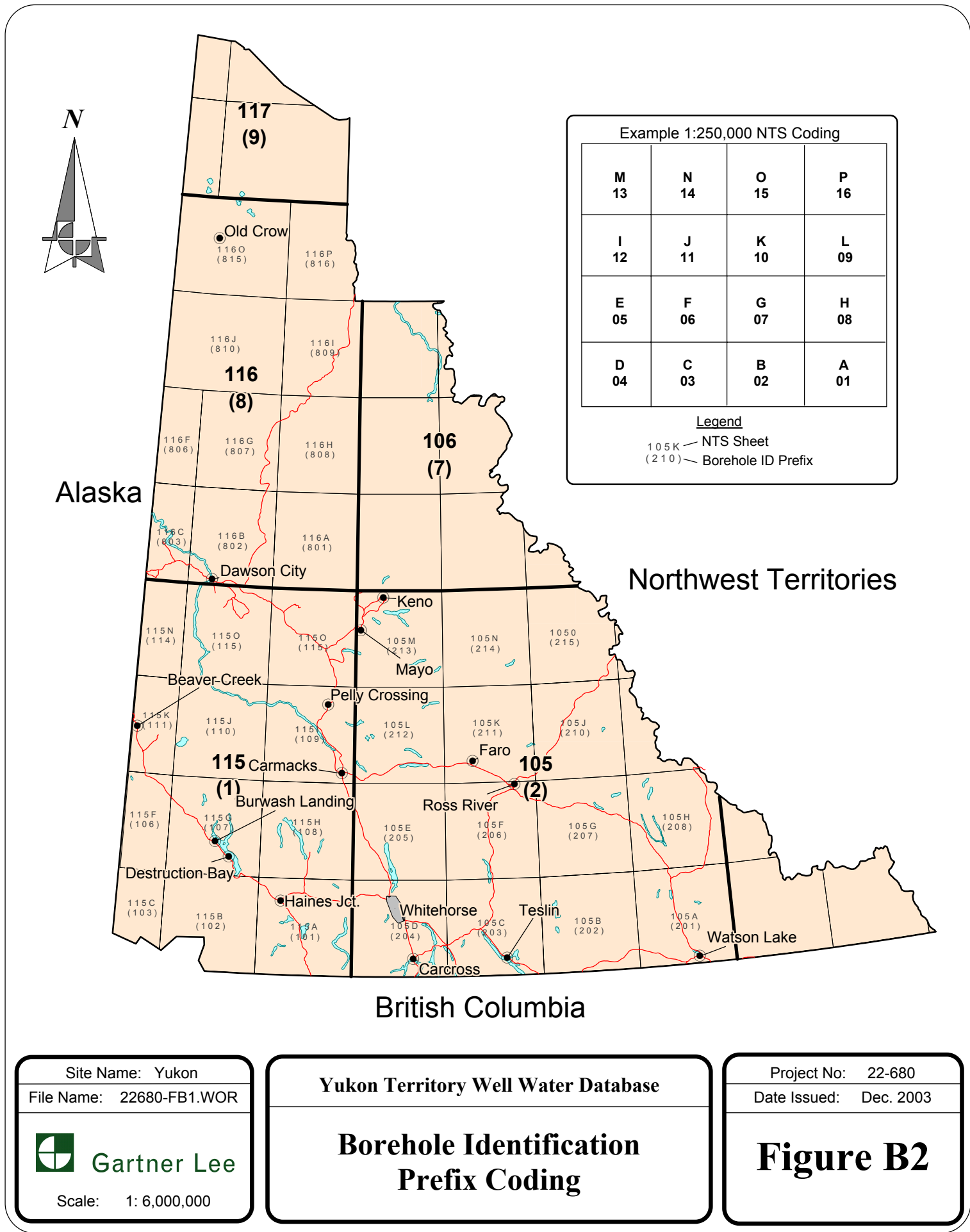
An example of this BoreholeID coding is as follows:

BoreholeID: 213140002

Where:

- 2 indicates 1:500,000 scale mapsheet 105
- 13 indicates 1:250,000 scale mapsheet M
- 14 indicates 1:50,000 scale mapsheet number 14
- 0002 indicates this is borehole #2 within this 1:50,000 scale mapsheet area.

Therefore, this borehole (No. 213140002) is the second borehole located in NTS mapsheet 105M/14, which in this example covers the community of Keno.



Site Name: Yukon
File Name: 22680-FB1.WOR



Gartner Lee

Scale: 1: 6,000,000

Yukon Territory Well Water Database

Borehole Identification Prefix Coding

Project No: 22-680
Date Issued: Dec. 2003

Figure B2

Properties

Date Created:	2/11/2003 11:24:56 AM	Def. Updatable:	True
Description:	Borehole location details - Primary Table	Last Updated:	12/22/2003 12:44:15 PM
OrderByOn:	True	RecordCount:	734

Columns

Name	Type	Size
Well_Name	Text	255
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1950	
Description:	Well name or description	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Well_Name	
Source Table:	Borehole	
BoreholeID	Number (Long)	4
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1755	
Decimal Places:	0	
Default Value:	0	
Description:	Unique well identifier code	
DisplayControl:	Text Box	
Ordinal Position:	2	
Required:	True	
Source Field:	BoreholeID	
Source Table:	Borehole	
Validation Text:	Borehole ID must be greater than 10000000000 or = -9 if null value	
Easting	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Caption:	UTM Easting	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1200	
Decimal Places:	0	
Description:	UTM Easting (NAD 83)	
DisplayControl:	Text Box	

	Ordinal Position:	3	
	Required:	True	
	Source Field:	Easting	
	Source Table:	Borehole	
	Validation Rule:	>10000 And <1000000	
	Validation Text:	UTM Easting must be greater than 10000 m and less than 1,000,000 m	
Northing		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Caption:	UTM Northing	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	1170	
	Decimal Places:	0	
	Description:	UTM Northing (NAD 83)	
	DisplayControl:	Text Box	
	Ordinal Position:	4	
	Required:	False	
	Source Field:	Northing	
	Source Table:	Borehole	
	Validation Rule:	>6300000 Or <7800000	
	Validation Text:	UTM Northing must be in Yukon (>6,300,000 and < 7,800,000)	
Well_Elev		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Caption:	Well Head Elevation	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	1305	
	Decimal Places:	2	
	Description:	Ground elevation at well head (metres above sea level) - Set value to '1' if elevation unknown	
	DisplayControl:	Text Box	
	Ordinal Position:	5	
	Required:	False	
	Source Field:	Well_Elev	
	Source Table:	Borehole	
	Validation Rule:	>0	
	Validation Text:	Elevation must be > 0	
Depth		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Caption:	Borehole total depth (m)	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	2460	

Decimal Places: Auto
Description: Total borehole depth, in metres below surface
DisplayControl: Text Box
Ordinal Position: 6
Required: True
Source Field: Depth
Source Table: Borehole
Validation Rule: 0 Or >0
Validation Text: Total Depth must be > 0, or = 0 if depth unknown

Hor_Acc Number (Integer) 2

AllowZeroLength: False
Attributes: Fixed Size
Bound Column: 1
Caption: Horizontal Accuracy Code
Collating Order: General
Column Count: 3
Column Heads: False
ColumnHidden: False
ColumnOrder: Default
ColumnWidth: 2160
Decimal Places: Auto
Default Value: 9
Description: Horizontal accuracy code
DisplayControl: Combo Box
Limit To List: False
List Rows: 8
List Width: 0twip
Ordinal Position: 7
Required: False
Row Source Type: Table/Query
Row Source: R_Hor_acc
Source Field: Hor_Acc
Source Table: Borehole

Vert_Acc Number (Integer) 2

AllowZeroLength: False
Attributes: Fixed Size
Bound Column: 1
Caption: Vertical Accuracy Code
Collating Order: General
Column Count: 2
Column Heads: False
ColumnHidden: False
ColumnOrder: Default
ColumnWidth: 4680
Decimal Places: 0
Description: Vertical (elevation) accuracy code
DisplayControl: Combo Box
Limit To List: False
List Rows: 8
List Width: 0twip
Ordinal Position: 8
Required: True

Row Source Type:		Table/Query	
Row Source:		R_Vert_acc_code	
Source Field:		Vert_Acc	
Source Table:		Borehole	
OldWell_ID		Text	255
AllowZeroLength:		False	
Attributes:		Variable Length	
Caption:		Old Well ID	
Collating Order:		General	
ColumnHidden:		False	
ColumnOrder:		Default	
ColumnWidth:		2385	
Description:		Old_well ID (from Wolf Creek/Pineridge water well database)	
DisplayControl:		Text Box	
Ordinal Position:		9	
Required:		False	
Source Field:		OldWell_ID	
Source Table:		Borehole	
UTMZone		Number (Integer)	2
AllowZeroLength:		False	
Attributes:		Fixed Size	
Caption:		UTM Zone	
Collating Order:		General	
ColumnHidden:		False	
ColumnOrder:		Default	
ColumnWidth:		660	
Decimal Places:		Auto	
Default Value:		8	
Description:		UTM Zone (zones 7 - 10 for Yukon)	
DisplayControl:		Text Box	
Ordinal Position:		10	
Required:		False	
Source Field:		UTMZone	
Source Table:		Borehole	
Validation Rule:		>6 And <11	
Validation Text:		UTM Zone must be in Yukon (Zones 7-10)	
Address		Text	255
AllowZeroLength:		False	
Attributes:		Variable Length	
Caption:		Street Address	
Collating Order:		General	
ColumnHidden:		False	
ColumnOrder:		Default	
ColumnWidth:		2685	
Description:		General street address	
DisplayControl:		Text Box	
Ordinal Position:		11	
Required:		False	
Source Field:		Address	
Source Table:		Borehole	

NTS	Text	7
AllowZeroLength:	True	
Attributes:	Variable Length	
Caption:	1:50,000 NTS Sheet No.	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	870	
Description:	1:50,000 National Topographic Series map sheet number	
DisplayControl:	Text Box	
Ordinal Position:	12	
Required:	False	
Source Field:	NTS	
Source Table:	Borehole	
Town	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Bound Column:	1	
Collating Order:	General	
Column Count:	1	
Column Heads:	False	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Description:	Community Name	
DisplayControl:	Combo Box	
Limit To List:	True	
List Rows:	8	
List Width:	0twip	
Ordinal Position:	13	
Required:	False	
Row Source Type:	Table/Query	
Row Source:	R_Town	
Source Field:	Town	
Source Table:	Borehole	
Data_Qual	Text	4
AllowZeroLength:	False	
Attributes:	Variable Length	
Bound Column:	1	
Caption:	Data Quality	
Collating Order:	General	
Column Count:	2	
Column Heads:	False	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	2145	
Description:	Data quality / completeness code	
DisplayControl:	Combo Box	
Limit To List:	False	
List Rows:	8	
List Width:	0twip	
Ordinal Position:	14	

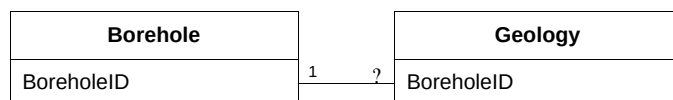
	Required:	True		
	Row Source Type:	Table/Query		
	Row Source:	R_Data_Qual_Code		
	Source Field:	Data_Qual		
	Source Table:	Borehole		
Type			Text	4
	AllowZeroLength:	False		
	Attributes:	Variable Length		
	Bound Column:	1		
	Collating Order:	General		
	Column Count:	2		
	Column Heads:	False		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	Default		
	Description:	Purpose of well		
	DisplayControl:	List Box		
	Ordinal Position:	15		
	Required:	False		
	Row Source Type:	Table/Query		
	Row Source:	R_Well_Type		
	Source Field:	Type		
	Source Table:	Borehole		
Drill_For			Text	255
	AllowZeroLength:	False		
	Attributes:	Variable Length		
	Collating Order:	General		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	Default		
	Description:	Person or organization well was drilled for		
	DisplayControl:	Text Box		
	Ordinal Position:	16		
	Required:	False		
	Source Field:	Drill_For		
	Source Table:	Borehole		
Driller			Text	4
	AllowZeroLength:	False		
	Attributes:	Variable Length		
	Bound Column:	1		
	Collating Order:	General		
	Column Count:	2		
	Column Heads:	False		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	Default		
	Description:	Drilling contractor who constructed well		
	DisplayControl:	List Box		
	Ordinal Position:	17		
	Required:	False		
	Row Source Type:	Table/Query		

Row Source:	R_Driller		
Source Field:	Driller		
Source Table:	Borehole		
Drill_Method		Text	5
AllowZeroLength:	False		
Attributes:	Variable Length		
Bound Column:	1		
Collating Order:	General		
Column Count:	1		
Column Heads:	False		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Description:	Drilling method used to construct well		
DisplayControl:	List Box		
Ordinal Position:	18		
Required:	False		
Row Source Type:	Table/Query		
Row Source:	R_Drill_Method		
Source Field:	Drill_Method		
Source Table:	Borehole		
Comp_Date		Date/Time	8
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Description:	Well completion date - if well deepened, enter completion date of work		
Input Mask:	99/99/0000;0;_		
Ordinal Position:	19		
Required:	False		
Source Field:	Comp_Date		
Source Table:	Borehole		
Reference		Text	50
AllowZeroLength:	False		
Attributes:	Variable Length		
Bound Column:	1		
Collating Order:	General		
Column Count:	3		
Column Heads:	False		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	6390		
Description:	General report reference if data from published report		
DisplayControl:	Combo Box		
Limit To List:	False		
List Rows:	8		
List Width:	0twip		
Ordinal Position:	20		

Required: False
Row Source Type: Table/Query
Row Source: References
Source Field: Reference
Source Table: Borehole

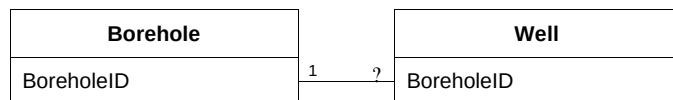
Relationships

BoreholeGeology



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

BoreholeWell



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

Table Indexes

Name	Number of Fields
BoreholeIDTemp	1
Clustered:	False
Distinct Count:	734
Foreign:	False
Ignore Nulls:	False
Name:	BoreholeIDTemp
Primary:	False
Required:	False
Unique:	True
Fields:	BoreholeID, Ascending
PrimaryKey	1
Clustered:	False
Distinct Count:	734
Foreign:	False
Ignore Nulls:	False
Name:	PrimaryKey
Primary:	True
Required:	True
Unique:	True

Fields:	BoreholeID, Ascending
WELL_ID	1
Clustered:	False
Distinct Count:	348
Foreign:	False
Ignore Nulls:	False
Name:	WELL_ID
Primary:	False
Required:	False
Unique:	False
Fields:	OldWell_ID, Ascending

Properties

Date Created:	2/11/2003 11:26:13 AM	Def. Updatable:	True
Description:	Water level, temperature, pH data etc.	Last Updated:	12/22/2003 12:25:33 PM
OrderByOn:	True	RecordCount:	115

Columns

Name	Type	Size
MonitorID	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
Default Value:	0	
Description:	Well/monitor which sample was collected from	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	True	
Source Field:	MonitorID	
Source Table:	Field_Measurements	
SampleID	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	2655	
Description:	Sample identifier, if sample collected for chemical analysis	
DisplayControl:	Text Box	
Ordinal Position:	2	
Required:	False	
Source Field:	SampleID	
Source Table:	Field_Measurements	
Date	Date/Time	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Description:	Sample/measurement date	
Input Mask:	99/99/0000;0;_	
Ordinal Position:	3	
Required:	True	
Source Field:	Date	

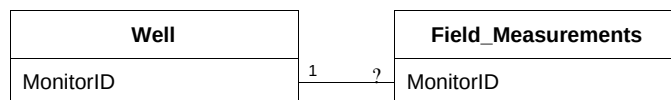
Source Table:	Field_Measurements		
Water_Level	Number (Double)	8	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Decimal Places:	Auto		
Default Value:	0		
Description:	Depth to water (m) below top of pipe surface		
DisplayControl:	Text Box		
Ordinal Position:	4		
Required:	False		
Source Field:	Water_Level		
Source Table:	Field_Measurements		
Stickup	Number (Single)	4	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Decimal Places:	2		
Default Value:	0		
Description:	Height of riser pipe (or inner casing) above ground surface (metres)		
DisplayControl:	Text Box		
Format:	Fixed		
Ordinal Position:	5		
Required:	False		
Source Field:	Stickup		
Source Table:	Field_Measurements		
pH	Number (Single)	4	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Decimal Places:	Auto		
Default Value:	0		
Description:	Field measurement of groundwater pH		
DisplayControl:	Text Box		
Ordinal Position:	6		
Required:	False		
Source Field:	pH		
Source Table:	Field_Measurements		
Conduct	Number (Double)	8	
AllowZeroLength:	False		
Attributes:	Fixed Size		

	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Default Value:	0	
	Description:	Field measurement of groundwater electrical conductivity (uS/cm)	
	DisplayControl:	Text Box	
	Ordinal Position:	7	
	Required:	False	
	Source Field:	Conduct	
	Source Table:	Field_Measurements	
Water_Temp		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Default Value:	0	
	Description:	Field measurement of groundwater temperature (degrees Celsius)	
	DisplayControl:	Text Box	
	Ordinal Position:	8	
	Required:	False	
	Source Field:	Water_Temp	
	Source Table:	Field_Measurements	
Hardness		Text	10
	AllowZeroLength:	False	
	Attributes:	Variable Length	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Description:	Field Measurement of groundwater hardness (mg/L as CaCO3)	
	DisplayControl:	Text Box	
	Ordinal Position:	9	
	Required:	False	
	Source Field:	Hardness	
	Source Table:	Field_Measurements	
Comments		Memo	-
	AllowZeroLength:	False	
	Attributes:	Variable Length	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	5910	
	Description:	Physical Description of sample including odour, colour etc.	
	Ordinal Position:	10	
	Required:	False	
	Source Field:	Comments	

Source Table: Field_Measurements

Relationships

WellField_Measurements



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

Table Indexes

Name	Number of Fields
BoreholeID	1
Clustered:	False
Distinct Count:	111
Foreign:	False
Ignore Nulls:	False
Name:	BoreholeID
Primary:	False
Required:	False
Unique:	False
Fields:	MonitorID, Ascending
SampleID	1
Clustered:	False
Distinct Count:	101
Foreign:	False
Ignore Nulls:	False
Name:	SampleID
Primary:	False
Required:	False
Unique:	False
Fields:	SampleID, Ascending
WellField_Measurements	1
Clustered:	False
Distinct Count:	111
Foreign:	True
Ignore Nulls:	False
Name:	WellField_Measurements
Primary:	False
Required:	False
Unique:	False
Fields:	MonitorID, Ascending

Properties

Date Created:	2/11/2003 11:26:37 AM	Def. Updatable:	True
Description:	Reported borehole geology	Last Updated:	12/22/2003 12:20:04 PM
OrderByOn:	True	RecordCount:	1571

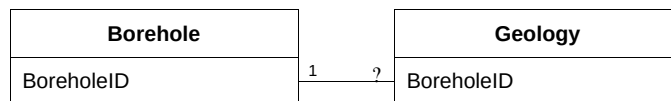
Columns

Name	Type	Size
BoreholeID	Number (Long)	4
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	BoreholeID	
Source Table:	Geology	
Litho_From	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
DisplayControl:	Text Box	
Ordinal Position:	2	
Required:	False	
Source Field:	Litho_From	
Source Table:	Geology	
Litho_To	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
DisplayControl:	Text Box	
Ordinal Position:	3	
Required:	False	
Source Field:	Litho_To	
Source Table:	Geology	

Geol_Orig	Text	255
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	6390	
DisplayControl:	Text Box	
Ordinal Position:	4	
Required:	False	
Source Field:	Geol_Orig	
Source Table:	Geology	

Relationships

BoreholeGeology



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

Table Indexes

Name	Number of Fields
BoreholeGeology	1
Clustered:	False
Distinct Count:	280
Foreign:	True
Ignore Nulls:	False
Name:	BoreholeGeology
Primary:	False
Required:	False
Unique:	False
Fields:	BoreholeID, Ascending
BoreholeIDTemp	1
Clustered:	False
Distinct Count:	280
Foreign:	False
Ignore Nulls:	False
Name:	BoreholeIDTemp
Primary:	False
Required:	False
Unique:	False
Fields:	BoreholeID, Ascending

Properties

Date Created:	2/11/2003 11:26:51 AM	Def. Updatable:	True
Description:	Reference table for Data Quality codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:54:24 AM
OrderByOn:	False	RecordCount:	3

Columns

Name	Type	Size
Data_Qual_Code	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	False	
Source Field:	Data_Qual_Code	
Source Table:	R_Data_Qual_Code	
Description	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Description	
Source Table:	R_Data_Qual_Code	

Table Indexes

Name	Number of Fields
Data_Qual_Code	1
Clustered:	False
Distinct Count:	3
Foreign:	False
Ignore Nulls:	False
Name:	Data_Qual_Code
Primary:	False
Required:	False
Unique:	False
Fields:	Data_Qual_Code, Ascending

Properties

Date Created:	2/11/2003 11:27:09 AM	Def. Updatable:	True
Description:	Reference table for Drilling Method codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:55:19 AM
OrderByOn:	False	RecordCount:	7

Columns

Name	Type	Size
Drill Method Code	Text	5
AllowZeroLength:	False	
Attributes:	Variable Length	
Bound Column:	1	
Collating Order:	General	
Column Count:	1	
Column Heads:	False	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Description:	Abbreviation of Drilling Method	
DisplayControl:	Combo Box	
Limit To List:	False	
List Rows:	8	
List Width:	0twip	
Ordinal Position:	0	
Required:	False	
Row Source Type:	Table/Query	
Source Field:	Drill Method Code	
Source Table:	R_Drill_Method	
Desription	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Description:	Drilling method	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Desription	
Source Table:	R_Drill_Method	

Table Indexes

Name	Number of Fields
Drill Method Code	1
Clustered:	False

Distinct Count:	7
Foreign:	False
Ignore Nulls:	False
Name:	Drill Method Code
Primary:	False
Required:	False
Unique:	False
Fields:	Drill Method Code, Ascending
PrimaryKey	1
Clustered:	False
Distinct Count:	7
Foreign:	False
Ignore Nulls:	False
Name:	PrimaryKey
Primary:	True
Required:	True
Unique:	True
Fields:	Drill Method Code, Ascending

Properties

Date Created:	2/11/2003 11:27:20 AM	Def. Updatable:	True
Description:	Reference table for Drilling Company codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:55:33 AM
OrderByOn:	False	RecordCount:	11

Columns

Name	Type	Size
Driller_code	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	False	
Source Field:	Driller_code	
Source Table:	R_Driller	
Drilling Company Names	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Drilling Company Names	
Source Table:	R_Driller	

Table Indexes

Name	Number of Fields
Driller_code	1
Clustered:	False
Distinct Count:	11
Foreign:	False
Ignore Nulls:	False
Name:	Driller_code
Primary:	False
Required:	False
Unique:	False
Fields:	Driller_code, Ascending

Properties

Date Created:	2/11/2003 11:27:34 AM	Def. Updatable:	True
Description:	Reference table for Horizontal Location Accuracy codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:55:58 AM
OrderByOn:	False	RecordCount:	9

Columns

Name	Type	Size
Hor_acc Code	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Bound Column:	1	
Collating Order:	General	
Column Count:	1	
Column Heads:	False	
ColumnHidden:	False	
ColumnOrder:	1	
ColumnWidth:	Default	
Decimal Places:	Auto	
Description:	Horizontal Accuracy Codes	
DisplayControl:	Combo Box	
Limit To List:	False	
List Rows:	8	
List Width:	0twip	
Ordinal Position:	0	
Required:	False	
Row Source Type:	Table/Query	
Source Field:	Hor_acc Code	
Source Table:	R_Hor_acc	
Margin of Error	Text	255
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1635	
Description:	Error range (in metres)	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Margin of Error	
Source Table:	R_Hor_acc	
Description	Text	255
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	

ColumnOrder:	Default
ColumnWidth:	9210
DisplayControl:	Text Box
Ordinal Position:	2
Required:	False
Source Field:	Description
Source Table:	R_Hor_acc

Table Indexes

Name	Number of Fields
PrimaryKey	1
Clustered:	False
Distinct Count:	9
Foreign:	False
Ignore Nulls:	False
Name:	PrimaryKey
Primary:	True
Required:	True
Unique:	True
Fields:	Hor_acc Code, Ascending

Properties

Date Created:	2/11/2003 11:28:32 AM	Def. Updatable:	True
Description:	Reference table for Town/Community codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:57:03 AM
OrderByOn:	True	RecordCount:	29
RowHeight:	270		

Columns

Name	Type	Size
TownCode	Text	5
AllowZeroLength:	False	
Attributes:	Variable Length	
Bound Column:	1	
Caption:	Reference Table for Town Codes	
Collating Order:	General	
Column Count:	1	
Column Heads:	False	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1650	
Description:	Town Abbreviation	
DisplayControl:	Text Box	
Limit To List:	False	
List Rows:	8	
List Width:	0twip	
Ordinal Position:	1	
Required:	False	
Row Source Type:	Table/Query	
Source Field:	TownCode	
Source Table:	R_Town	
Town	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Description:	Actual Town Name	
DisplayControl:	Text Box	
Ordinal Position:	2	
Required:	False	
Source Field:	Town	
Source Table:	R_Town	

Table Indexes

Name	Number of Fields
------	------------------

Town Code	1
Clustered:	False
Distinct Count:	29
Foreign:	False
Ignore Nulls:	False
Name:	Town Code
Primary:	False
Required:	False
Unique:	False
Fields:	TownCode, Ascending

Properties

Date Created:	2/11/2003 11:28:43 AM	Def. Updatable:	True
Description:	Reference table for Vertical Location Accuracy codes (lookup for Borehole table)	Last Updated:	12/22/2003 11:56:48 AM
OrderByOn:	False	RecordCount:	9

Columns

Name	Type	Size
Vert_acc_Code	Number (Long)	4
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
Default Value:	0	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	False	
Source Field:	Vert_acc_Code	
Source Table:	R_Vert_acc_code	
Description	Text	200
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	6045	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Description	
Source Table:	R_Vert_acc_code	

Table Indexes

Name	Number of Fields
Vert_acc_Code	1
Clustered:	False
Distinct Count:	9
Foreign:	False
Ignore Nulls:	False
Name:	Vert_acc_Code
Primary:	False
Required:	False

Unique:	False
Fields:	Vert_acc_Code, Ascending

Properties

Date Created:	2/11/2003 11:28:55 AM	Def. Updatable:	True
Description:	Reference table for Well/Monitor Status codes (lookup for Well table)	Last Updated:	12/22/2003 11:57:17 AM
OrderByOn:	False	RecordCount:	10

Columns

Name	Type	Size
Well_Status_Code	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	False	
Source Field:	Well_Status_Code	
Source Table:	R_Well_Status	
Description	Text	100
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	5775	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Description	
Source Table:	R_Well_Status	

Table Indexes

Name	Number of Fields
Well_Status_Code	1
Clustered:	False
Distinct Count:	10
Foreign:	False
Ignore Nulls:	False
Name:	Well_Status_Code
Primary:	False
Required:	False
Unique:	False
Fields:	Well_Status_Code, Ascending

Properties

Date Created:	2/11/2003 11:29:08 AM	Def. Updatable:	True
Description:	Reference table for Well Type codes (lookup for Well table)	Last Updated:	12/22/2003 11:57:31 AM
OrderByOn:	False	RecordCount:	16

Columns

Name	Type	Size
Well_Type_Code	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	False	
Source Field:	Well_Type_Code	
Source Table:	R_Well_Type	
description	Text	250
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	5415	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	description	
Source Table:	R_Well_Type	

Table Indexes

Name	Number of Fields
Well_Type_Code	1
Clustered:	False
Distinct Count:	16
Foreign:	False
Ignore Nulls:	False
Name:	Well_Type_Code
Primary:	False
Required:	False
Unique:	False
Fields:	Well_Type_Code, Ascending

Properties

Date Created:	2/11/2003 11:29:20 AM	Def. Updatable:	True
Description:	Report and data source references; bibliography (lookup for Borehole table)	Last Updated:	12/22/2003 11:58:27 AM
OrderByOn:	False	RecordCount:	24

Columns

Name	Type	Size
Ref_ID	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	1	
ColumnWidth:	2280	
DisplayControl:	Text Box	
Ordinal Position:	0	
Required:	True	
Source Field:	Ref_ID	
Source Table:	References	
Author	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	3900	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Author	
Source Table:	References	
Date	Date/Time	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Format:	Short Date	
Ordinal Position:	2	
Required:	False	
Source Field:	Date	
Source Table:	References	
Title	Text	250
AllowZeroLength:	False	

		Attributes:	Variable Length	
		Collating Order:	General	
		ColumnHidden:	False	
		ColumnOrder:	Default	
		ColumnWidth:	4125	
		DisplayControl:	Text Box	
		Ordinal Position:	3	
		Required:	False	
		Source Field:	Title	
		Source Table:	References	
Prepared For			Text	50
		AllowZeroLength:	False	
		Attributes:	Variable Length	
		Collating Order:	General	
		ColumnHidden:	False	
		ColumnOrder:	Default	
		ColumnWidth:	Default	
		DisplayControl:	Text Box	
		Ordinal Position:	4	
		Required:	False	
		Source Field:	Prepared For	
		Source Table:	References	
Location			Text	50
		AllowZeroLength:	False	
		Attributes:	Variable Length	
		Collating Order:	General	
		ColumnHidden:	False	
		ColumnOrder:	Default	
		ColumnWidth:	Default	
		DisplayControl:	Text Box	
		Ordinal Position:	5	
		Required:	False	
		Source Field:	Location	
		Source Table:	References	
Other			Text	50
		AllowZeroLength:	False	
		Attributes:	Variable Length	
		Collating Order:	General	
		ColumnHidden:	False	
		ColumnOrder:	Default	
		ColumnWidth:	Default	
		DisplayControl:	Text Box	
		Ordinal Position:	6	
		Required:	False	
		Source Field:	Other	
		Source Table:	References	

Table Indexes

<u>Name</u>	<u>Number of Fields</u>
-------------	-------------------------

PrimaryKey	1
Clustered:	False
Distinct Count:	24
Foreign:	False
Ignore Nulls:	False
Name:	PrimaryKey
Primary:	True
Required:	True
Unique:	True
Fields:	Ref_ID, Ascending
Ref_ID	1
Clustered:	False
Distinct Count:	24
Foreign:	False
Ignore Nulls:	False
Name:	Ref_ID
Primary:	False
Required:	False
Unique:	False
Fields:	Ref_ID, Ascending

Properties

Date Created:	2/11/2003 11:29:33 AM	Def. Updatable:	True
Description:	Well construction and other details	Last Updated:	12/22/2003 12:45:54 PM
OrderByOn:	True	RecordCount:	731

Columns

Name	Type	Size
Monitor_Name	Text	50
AllowZeroLength:	False	
Attributes:	Variable Length	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	2190	
Description:	Monitor / Well name (allows multiple monitors per borehole)	
DisplayControl:	Text Box	
Ordinal Position:	1	
Required:	False	
Source Field:	Monitor_Name	
Source Table:	Well	
MonitorID	Number (Double)	8
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	1470	
Decimal Places:	0	
Default Value:	0	
Description:	Unique Monitor / Well Identifier (allows multiple monitors per borehole)	
DisplayControl:	Text Box	
Format:	Fixed	
Ordinal Position:	2	
Required:	True	
Source Field:	MonitorID	
Source Table:	Well	
BoreholeID	Number (Long)	4
AllowZeroLength:	False	
Attributes:	Fixed Size	
Collating Order:	General	
ColumnHidden:	False	
ColumnOrder:	Default	
ColumnWidth:	Default	
Decimal Places:	Auto	
Default Value:	0	
Description:	Unique Borehole Identifier	
DisplayControl:	Text Box	

	Ordinal Position:	3		
	Required:	True		
	Source Field:	BoreholeID		
	Source Table:	Well		
Scrn_From			Number (Double)	8
	AllowZeroLength:	False		
	Attributes:	Fixed Size		
	Collating Order:	General		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	1185		
	Decimal Places:	Auto		
	Description:	Top of screened interval (in metres below ground surface)		
	DisplayControl:	Text Box		
	Ordinal Position:	4		
	Required:	False		
	Source Field:	Scrn_From		
	Source Table:	Well		
Scrn_To			Number (Double)	8
	AllowZeroLength:	False		
	Attributes:	Fixed Size		
	Collating Order:	General		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	930		
	Decimal Places:	Auto		
	Description:	Bottom of screened interval (in metres below ground surface)		
	DisplayControl:	Text Box		
	Ordinal Position:	5		
	Required:	False		
	Source Field:	Scrn_To		
	Source Table:	Well		
Scrn_Type			Memo	-
	AllowZeroLength:	False		
	Attributes:	Variable Length		
	Collating Order:	General		
	ColumnHidden:	False		
	ColumnOrder:	Default		
	ColumnWidth:	1785		
	Description:	Description of type of well screen		
	Ordinal Position:	6		
	Required:	False		
	Source Field:	Scrn_Type		
	Source Table:	Well		
Status			Text	4
	AllowZeroLength:	False		
	Attributes:	Variable Length		
	Bound Column:	1		
	Collating Order:	General		
	Column Count:	2		

	Column Heads:	False	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	3795	
	Description:	Well status	
	DisplayControl:	Combo Box	
	Limit To List:	False	
	List Rows:	8	
	List Width:	0twip	
	Ordinal Position:	7	
	Required:	False	
	Row Source Type:	Table/Query	
	Row Source:	R_Well_Status	
	Source Field:	Status	
	Source Table:	Well	
WaterDepth		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	1530	
	Decimal Places:	2	
	Default Value:	0	
	Description:	Original static water level (m below top of pipe/casing)	
	DisplayControl:	Text Box	
	Format:	Fixed	
	Ordinal Position:	13	
	Required:	False	
	Source Field:	WaterDepth	
	Source Table:	Well	
Diametre		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	1560	
	Decimal Places:	Auto	
	Description:	Well outside nominal diametre in centimetres - if telescoped, note in Comment field	
	DisplayControl:	Text Box	
	Ordinal Position:	14	
	Required:	False	
	Source Field:	Diametre	
	Source Table:	Well	
Casing_Stickup		Number (Single)	4
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	

	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	2	
	Default Value:	0	
	Description:	Inner well casing stickup above ground surface (m)	
	DisplayControl:	Text Box	
	Ordinal Position:	15	
	Required:	False	
	Source Field:	Casing_Stickup	
	Source Table:	Well	
Aqui_Type		Text	255
	AllowZeroLength:	False	
	Attributes:	Variable Length	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	1155	
	Description:	General aquifer type code	
	DisplayControl:	Text Box	
	Ordinal Position:	16	
	Required:	False	
	Source Field:	Aqui_Type	
	Source Table:	Well	
Yield		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Description:	Estimated well yield (L/s) - either Long-term well yield from pumping test analysis, or drillers estimate	
	DisplayControl:	Text Box	
	Ordinal Position:	17	
	Required:	False	
	Source Field:	Yield	
	Source Table:	Well	
Pump_Cap		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Description:	Installed pump capacity (L/s)	
	DisplayControl:	Text Box	
	Ordinal Position:	18	
	Required:	False	
	Source Field:	Pump_Cap	

Source Table:	Well		
Pump_Test	Date/Time	8	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Description:	Date of most comprehensive pumping test (see Reference in Borehole Table for data source)		
Format:	Short Date		
Input Mask:	99/99/00;0;_		
Ordinal Position:	19		
Required:	False		
Source Field:	Pump_Test		
Source Table:	Well		
T	Number (Double)	8	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Decimal Places:	Auto		
Description:	Reported Transmissivity (m2/day) - use best value if multiple estimates		
DisplayControl:	Text Box		
Ordinal Position:	20		
Required:	False		
Source Field:	T		
Source Table:	Well		
K	Number (Double)	8	
AllowZeroLength:	False		
Attributes:	Fixed Size		
Collating Order:	General		
ColumnHidden:	False		
ColumnOrder:	Default		
ColumnWidth:	Default		
Decimal Places:	Auto		
Description:	Reported Hydraulic Conductivity (m/s) - use best or mean value if multiple estimates		
DisplayControl:	Text Box		
Ordinal Position:	21		
Required:	False		
Source Field:	K		
Source Table:	Well		
Chemistry	Yes/No	1	
AllowZeroLength:	False		

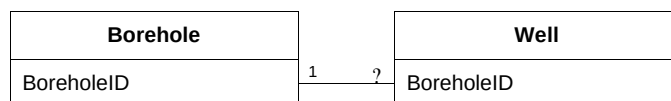
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Description:	Water chemistry available (see Reference in Borehole Table for data source)	
	DisplayControl:	Text Box	
	Format:	Yes/No	
	Ordinal Position:	22	
	Required:	False	
	Source Field:	Chemistry	
	Source Table:	Well	
pH		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Description:	First reported water pH	
	DisplayControl:	Text Box	
	Ordinal Position:	23	
	Required:	False	
	Source Field:	pH	
	Source Table:	Well	
Conduct		Number (Double)	8
	AllowZeroLength:	False	
	Attributes:	Fixed Size	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Decimal Places:	Auto	
	Description:	First reported water electrical conductivity (uS/cm)	
	DisplayControl:	Text Box	
	Ordinal Position:	24	
	Required:	False	
	Source Field:	Conduct	
	Source Table:	Well	
Comments		Memo	-
	AllowZeroLength:	False	
	Attributes:	Variable Length	
	Collating Order:	General	
	ColumnHidden:	False	
	ColumnOrder:	Default	
	ColumnWidth:	Default	
	Description:	Misc. comment field for other notes	
	Ordinal Position:	29	
	Required:	False	

Source Field:
Source Table:

Comments
Well

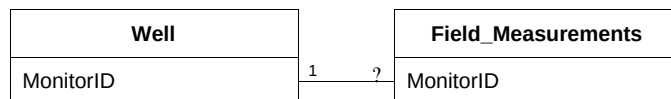
Relationships

BoreholeWell



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

WellField_Measurements



Attributes: Enforced, Cascade Updates, Cascade Deletes
Attributes: One-To-Many

Table Indexes

Name	Number of Fields
~~temp~index~name0	1
Clustered:	False
Distinct Count:	731
Foreign:	False
Ignore Nulls:	False
Name:	~~temp~index~name0
Primary:	False
Required:	False
Unique:	False
Fields:	MonitorID, Ascending
BoreholeIDTemp	1
Clustered:	False
Distinct Count:	711
Foreign:	False
Ignore Nulls:	False
Name:	BoreholeIDTemp
Primary:	False
Required:	False
Unique:	False
Fields:	BoreholeID, Ascending
BoreholeWell	1
Clustered:	False

Distinct Count:	711
Foreign:	True
Ignore Nulls:	False
Name:	BoreholeWell
Primary:	False
Required:	False
Unique:	False
Fields:	BoreholeID, Ascending
MonitorID	1
Clustered:	False
Distinct Count:	731
Foreign:	False
Ignore Nulls:	False
Name:	MonitorID
Primary:	False
Required:	False
Unique:	True
Fields:	MonitorID, Ascending