Yukon

Aquifer Mapping Report

Town of Watson Lake

April, 2023

Aquifer Mapping
Town of Watson Lake, Yukon

Government of Yukon
Water Resources Branch

Authors
WSP Canada Inc.

Background

The purpose of the project was to identify, delineate, and classify aquifers underlying the boundary of the Town of Watson Lake and build a foundation for future hydrogeological work in the area. This report presents the geological setting and relevant background information for the study area, methods used to process and interpret the subsurface hydrogeological data, and resultant aquifer delineations and classification according to the British Columbia (BC) aquifer classification system.

Reviewers and contributors:

Government of Yukon:
- Department of Environment, Water Resources Branch
- Department of Energy, Mines and Resources, Yukon Geological Survey

Liard First Nation
Dena Kayeh Institute
Town of Watson Lake
Government of Canada, Natural Resources Canada, Geological Survey of Canada
Yukon University

Copies available from:
Government of Yukon
Water Resources Branch, V-310
Box 2703, Whitehorse, Yukon Y1A 2C6
Phone 867-667-3195
Email: water.resources@yukon.ca
Online: Yukon.ca and open.yukon.ca

Citation:
WSP Canada Inc. 2025. Aquifer Mapping Report: Town of Watson Lake. Yukon Water Resources Branch, Whitehorse, Yukon, Canada.

Disclaimer:

Study limitations

This document has been prepared for the purposes of identifying and mapping aquifers in the vicinity of Watson Lake and is provided for the exclusive use of the Government of Yukon Water Resource Branch (WRB).

The scope of work for this study was intended to provide a regional-scale overview only and did not include such items as detailed subsurface investigations or site-specific hydrogeological assessments. In preparing this document, WSP Canada Inc (WSP) has relied in good faith on information provided by sources noted in this document. We accept no responsibility for any deficiency, misstatements or inaccuracy contained in this document as a result of omissions, misstatements, or fraudulent acts of others.

The factual information, descriptions, interpretations, comments, conclusions, and recommendations contained herein are specific to the project described in this document and do not apply to any other project or site. Plans, electronic files and similar material used to develop this document are instruments of service, not products. If new information is discovered in the future, WSP should be requested to re-evaluate the conclusions of this document and to provide amendments as required prior to any reliance upon the information presented herein.

The hydrogeological services performed as described in this document were conducted in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practising under similar conditions, subject to the quantity and quality of available data, the time limits, and financial and physical constraints applicable to the services. Unless otherwise specified, the results of previous work provided by sources other than WSP and quoted and/or used herein are considered as having been obtained according to recognised and accepted professional rules and practices, and therefore deemed valid. WSP makes no warranty, expressed or implied, and assumes no liability with respect to the use of the information contained in this document at the subject area, or any other site, for other than its intended purpose.

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

Executive summary

The purpose of the project was to identify, delineate, and classify aquifers within the boundary of the Town of Watson Lake and build a foundation for the development of a conceptual hydrogeological model for the area. This report presents the geological setting and relevant background information for the study area, methods used to process and interpret the subsurface hydrogeological data and resultant aquifer delineations and classification according to the BC aquifer classification system (Bernardinucci and Ronneseth, 2002).

The Town of Watson Lake (Watson Lake) is located in southeastern Yukon, approximately 350 km east of Whitehorse and approximately 7 km north of the British Columbia border. Watson Lake has a population of approximately 1200 residents and is home to the Kaska Dena, the people of Liard First Nation (LFN). The Town of Watson Lake is situated at the southeastern end of Watson Lake and north of the Liard River. The Watson Lake map area has been glaciated many times during the Quaternary period (the last 2.65 million years). As summarized in Lipovsky and McKenna (2005), the majority of glacial deposits are from the latest glaciation, which is known as the McConnell Glaciation. During this late Wisconsinan (~25,000-21,000 years ago) global advance of ice sheets, ice flowed in an easterly direction out of the Cassiar Mountains and in a southeasterly direction out of the Pelly and Selwyn mountains, following the Tintina Trench / Liard Lowland. South of Watson Lake, ice flowed in a northeast to easterly direction in the lower Dease River and Lower Post areas. The valley deposits are described in detail by Lipovsky and McKenna (2005):

"At the close of the McConnell Glaciation (~10,000 years ago) the Cordilleran Ice Sheet began to retreat toward source areas northwest and southwest of Watson Lake. During a period of re-advance and ice stagnation, the Liard River was dammed in the Lower Post area and an extensive glacial lake formed in the Liard River Valley. A thick sequence of fine-grained sediments were deposited at the bottom of this lake, which shrank and eventually drained as the ice sheet thinned and further retreated. Ongoing melt of more distal ice deposited outwash plains of sand and gravel up to 30 m thick above the lake sediments along the Liard River valley floor. Ice stagnation during deglaciation also left behind blocks of ice that became buried by outwash. Steep sided depressions and pitted, hummocky terrain were formed when the ice blocks subsequently melted out; Watson Lake itself may have formed from melt of a large stagnant block of ice. Glacial meltwater also carved deep meltwater channels through bedrock in various locations north and northeast of town."

Material descriptions and glacial history of the area generally suggest well-drained units form the bulk of surface sediments (glaciofluvial) with impermeable glaciolacustrine and till deposits at some depth. Glaciolacustrine deposits are inferred to be relatively laterally continuous. Thick impermeable till deposits are likely relatively continuous over low-elevation surfaces and thinner or even absent in the uplands area.

For the purposes of this report, an "aquifer" in unconsolidated materials (i.e., soil) is considered to be a geological deposit or formation that has high permeability relative to its surroundings and which readily transmits water to wells and springs. Bedrock aquifers have not been delineated in this report due to limited hydrogeological information and high variability in local permeability, though it is noted that in many cases wells drilled into the bedrock may yield a small groundwater supply suitable for domestic use.

Three proven aquifers and three potential aquifers were identified within the study area as part of this project.

1. The Fan Aquifer is an unconfined sand and gravel aquifer constrained to the glaciofluvial fan deposit in the vicinity of the airport.
2. The Glaciofluvial Aquifer is constrained to the glaciofluvial sands and gravels in the valley south-east of Watson Lake.
3. The Deltaic Package Aquifer is a partially confined sand (some gravel) aquifer that underlies the unconfined Glaciofluvial Aquifer.
4. The Potential Deep Sands and Gravel Aquifer is a confined sand and gravel deposit identified only in the YOWN-2209 S/D stratigraphic borehole. Insufficient data is available at this time to delineate these deposits as an aquifer although it is suspected that this aquifer may exist throughout the bottom of the valley.
5. The Potential Deep Glacial Outwash Sands and Gravel Aquifer is a confined sand and gravel aquifer southwest of Watson Lake and is inferred to extend to the edge of the Liard Valley. Insufficient data is available at this time to delineate these deposits as an aquifer, its extent is uncertain and inferred from spatially limited environmental monitoring wells and exposures on the river valley with no water supply wells.
6. The Potential Glaciofluvial Aquifer (Liard River Valley), is an unconfined aquifer located in the Liard River Valley inferred to be part of the same depositional event as the Glaciofluvial Aquifer. However, limited subsurface information, limited information on the degree of saturation encountered in the environmental holes that intersect the unit, and lack of water supply wells in the area prevent the mapping of this as an aquifer at this time.

[This page intentionally left blank]

TABLE OF CONTENTS

Appendices

Place Names and Acronyms

Kaska Place Names

Efforts were made to assign Kaska place names to all named aquifer units, but due to capacity and timing constraints these names will be added at a later date.

Acronyms

CDEM	Canadian Digital Elevation Model
DKI	Dena Kayeh Institute
GCDWQG	Government of Canada Drinking Water Guidelines
GSC	Geological Survey of Canada
GW	Groundwater
ID	Identifier or Identification number
LFN	Liard First Nation
LiDAR	Light Detection and Ranging
masl	Metres above sea level
mbgs	Metres below ground surface
YG WRB	Government of Yukon Water Resources Branch
YGS	Yukon Geological Survey
YOWN	Yukon Observation Well Network
YWWR	Yukon Water Well Registry

Study Area Location

The Town of Watson Lake (Watson Lake) is located in southeastern Yukon, approximately 350 km east of Whitehorse and approximately 7 km north of the British Columbia border. Watson Lake has a population of approximately 1200 residents and is home to the Kaska Dena, the people of Liard First Nation (LFN), who traditionally speak Kaska. The Town of Watson Lake is situated at the southeastern end of Watson Lake and north of the Liard River. For the purposes of aquifer mapping, the "Study Area" was constrained to the approximate extent of available LiDAR, which encompasses approximately 65% (81 km^2) of the 125 km^2 community boundary of Watson Lake, shown below in Figure 1.

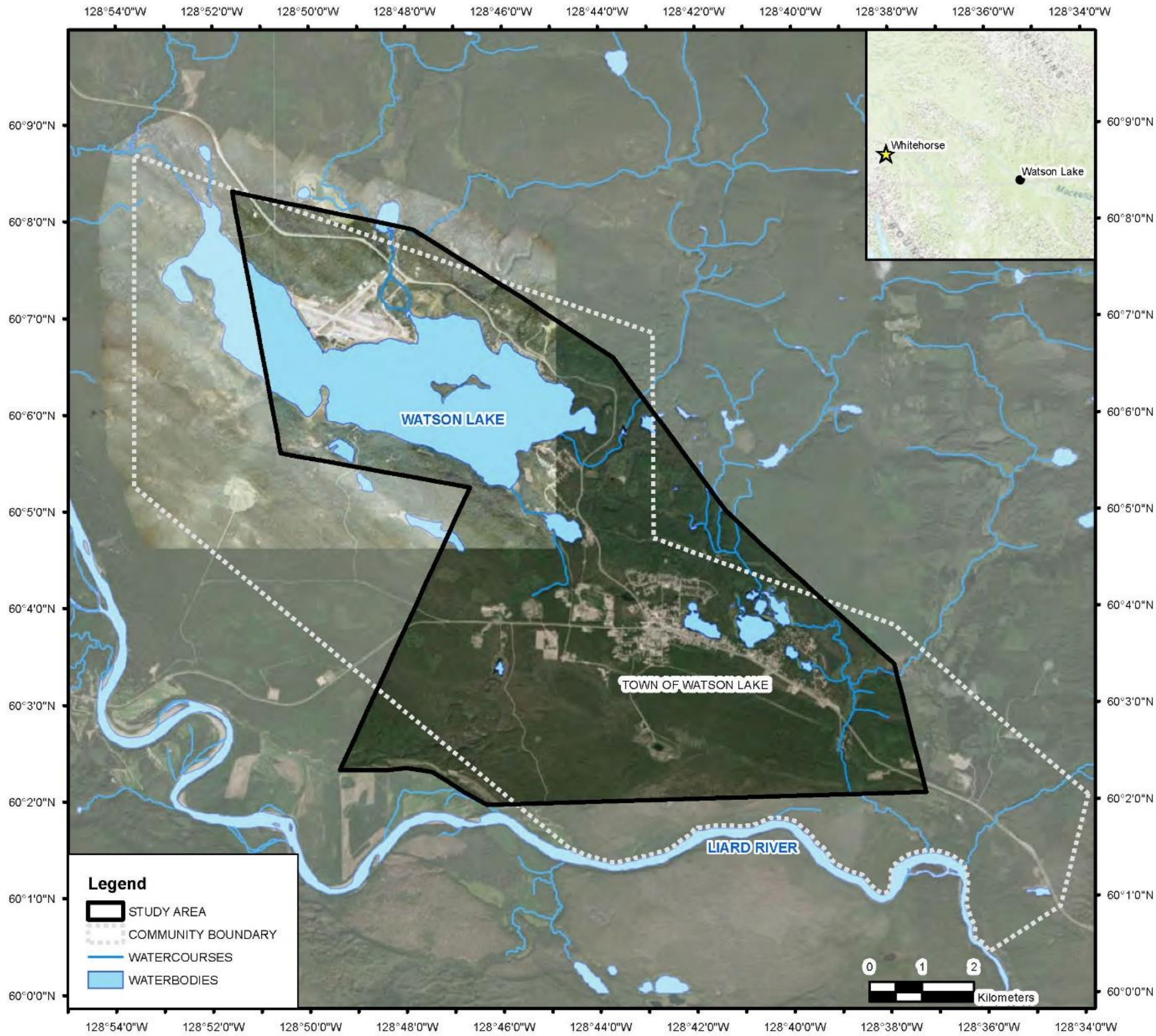


Figure 1. Study Area

Methods

Subsurface geological and hydrogeological data was compiled, preprocessed, standardized, and imported into Leapfrog Works (v 2022.1.0), a commercially available 3D subsurface modelling software package, for interpretation and aquifer delineation. The data sources and workflows for the preprocessing, lithological standardization, 3D visualization and interpretation are described in the subsections below.

Data Sources

WSP Canada Inc. (WSP) conducted a data gathering exercise to obtain Quaternary geological and hydrogeological information for the Study Area by means of correspondence with the Government of Yukon Department of Environment, Water Resources Branch (WRB)and on-line searches of publicly available information sources including the Yukon WaterWell Registry (YWWR). The WRB coordinated the gathering of information from wellsassociated with LFN, the Dena Kayeh Institute (DKI), and the Town of Watson Lake as wellas available geological and subsurface data from other government agencies andcon-sultants. Table 1 provides a summary of the data that was compiled.

Table 1: Summary of Data Sources

Source	Data Type	Data Coverage
Yukon Water Well Registry (YWWR)	Well locations and well logs for public and private water supply wells, environmental monitoring wells and industrial / commercial wells.	234 wells total, 168 wells with lithology available
1 m resolution bare earth LiDAR data from Geomatics Yukon (2019)	High resolution digital elevation data also used to support accurate vertical positioning of boreholes.	Area slightly smaller than the Town of Watson Lake community boundary
Canadian Digital Elevation Model (CDEM)	Lower resolution digital elevation data used where high resolution data was not available.	Upper Liard and Lower Post

Source	Data Type	Data Coverage
Surficial Geology Map of Watson Lake (Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial geology of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Open File 2005-7.)	Finer scale mapped distribution of surficial geological units and descriptions.	Regional coverage of the Watson Lake area
Yukon Observation Well Network (YOWN) Subsurface Investigation	Two stratigraphic boreholes with observation wells.	Two locations in the Town of Watson Lake

The primary source of subsurface information for the project was the YWWR database. The YWWR contained a total of 234 well records, 168 of which had lithological information, and over 1120 unique lithological intervals for the Study Area at the time of download in June 2021.

Groundwater wells in the area are used as private domestic wells, public drinking water supply wells, environmental monitoring wells and as a water supply for commercial or industrial processes. The groundwater wells in the Study Area range in depth from approximately 2 m to 97 m (geometric mean of 12 m), with 46 locations drilled to a depth of greater than 30 m. Installation depths for well screens range from 5 m to 98 m, with an average installation depth of between 16 and 18 metres below ground surface (mbgs) and an average screened interval length of 1.5 m. Lithology descriptions provided on water well records generally include grain-size descriptions such as silt and clay, silty-sand, sand, sand and gravel, and gravel. These lithology descriptions are dependent on the driller's observations and log from the time of drilling and are highly variable with respect to the amount of detail and degree of quality. There is only limited information regarding the degree of saturation, cohesion, plasticity, compaction, and other geotechnical descriptors. The locations of water well records are clustered around populated areas.

Subsurface information from geotechnical investigations and environmental investigations is more spatially distributed throughout the Watson Lake area. Geotechnical and environmental logs provide more detailed lithological descriptions including descriptive modifiers related to degree of saturation, cohesion, plasticity and compaction; however, the depth of investigation is typically shallower. In general, the geotechnical information tends to be shallow averaging approximately 4 m in depth (shallow boreholes and test pits), with only four locations extending to a depth greater than 10 m.

Following a review of the available data in the Study Area and a summary of the data gaps for aquifer mapping, the WRB advanced stratigraphic boreholes at two locations in Watson Lake to obtain additional deep data, increase the confidence in the stratigraphic correlations, and to further the understanding of the depositional environment. The first borehole was advanced to 8.2 mbgs and intersected bedrock at a depth of 6.4 mbgs. This borehole was completed with a shallow monitoring well (YOWN-2208). A second borehole, located further east, was advanced to a greater depth and subsequently completed with two nested monitoring wells (YOWN-2209S and YOWN-2209D). This stratigraphic borehole represents an important control point for the geological and hydrostratigraphic interpretation (Section 3.1).

High resolution topographic information in the form of 1 m resolution bare earth LiDAR data from 2019 was provided by Geomatics Yukon for the full extent of the Study Area. Outside of the municipal boundary, lower resolution topographic data from the 20 m resolution CDEM was utilized for the extrapolation of bedrock depth from valley side slopes. Information on the depth to bedrock within the center of the main valleys is limited (five locations). Bedrock is intersected at a number of locations along the western edge of the Watson Lake between 2 m and 30 m depth. Shallow bedrock was intersected at the newly-drilled YOWN-2208, but was not intersected at the newly-drilled YOWN-2209 S/D.

Limited information exists on the depth and morphology of the bedrock surface within the valleys. The bedrock surface below the thick valley sediments was estimated using a series of 2D planes placed coincident to bedrock side slopes from the topographic data and extended to depth below the valley. Points placed on these surfaces were used as control points together with the bedrock depth from boreholes that intersected bedrock to generate the top of bedrock as an offset surface from topography generally assuming a U-shaped valley in the vicinity of Watson Lake and slope downwards below the Liard valley. In the highlands, the bedrock surface is assumed to mimic topography where unconsolidated sediments are relatively thin (generally < 5 m). Generating a bedrock surface using an offset surface from topography and assuming a U-shaped valley is a standard method for estimating the bedrock surface in a valley in an area where limited information is available. Due to the limited information of definitive bedrock contacts within the valley, this assumed bedrock surface should be considered conceptual only with a high degree of uncertainty. Small-scale morphological features in the assumed bedrock surface are an artifact of the method used to generate the surface and may not be indicative of actual conditions.

Data Standardization

Well information and lithological descriptors are variable in terms of documentation and overall data quality, with substantial variation depending on the age of the well record and drilling company. Common types of preprocessing that was conducted as part of this study include:

- Conversion from imperial units to metric
- Manual entry of lithological information from the YWWR and well records
- Standardization of lithological descriptors

Given the variability of the raw lithology descriptors, standardization of the lithological dataset was required for effective interpretation of subsurface stratigraphy and conditions. The method of standardization primarily consisted of keyword scripts to extract relevant data descriptors from the lithology field. Once the relevant lithological data were extracted, they were classified on the basis of sediment texture (i.e. relative proportions of sand, gravel, silt and clay sized particles) into groups that were expected to behave in a hydraulically similar manner. These sediment textural groupings were implemented in the 3D subsurface model and were used to facilitate the geological and hydrostatigraphic interpretations described in Sections 3.0 and 4.0, respectively. Table 2, below, presents the main lithological descriptors and their associated sediment textural grouping.

Table 2: Lithological Descriptor Standardization

Lithological Descriptor	Sediment Textural Grouping
Sand and Gravel	Sand and Gravel
Gravelly Sand/ Sandy Gravel	
Silty sand and Gravel	
Sand (Fine / Medium / Coarse / Clean)	Sand
Silty Sand	Silt / Sand
Sandy Silt	
Silt	Silt
Clay	Clay
Silty Clay	
Till	Till
Clay, Sand, Gravel	
Silt, Sand and Cobbles	
Bedrock	Bedrock

It should be noted that these groupings and classifications are methods used only to facilitate visualization of the data in 3D for the interpreter; the full raw lithologies were still queried by the interpreter during the aquifer mapping and delineation process to ensure that professional judgement was applied throughout the process as opposed to being strictly an automated process.

Dimensional Visualization and Hydrostratigraphic Interpretation

To conduct the 3D hydrostratigraphic visualization and interpretation, standardized datasets for lithology, degree of saturation, and groundwater levels / depths to water were imported into Leapfrog Works (v 2022.1.0) for 3D rendering. Well collar elevations were frequently unavailable or, where available, were typically low accuracy. To vertically reference well or borehole collars, collars were assigned elevations by projecting them onto the topographic surface in the 3D model, which was defined by the high-resolution LiDAR mapping. This allowed for vertical referencing of all associated wells and lithological data within the 3D space of the subsurface model; however, it also meant that vertical elevation errors could be introduced where the associated well record has low horizontal accuracy in an area of high topographic relief. Outside of the LiDAR coverage and at the edge of the low-resolution DEM, vertical walls are sometimes present. These are an artifact of the difference between the LiDAR and low-resolution DEM and do not reflect actual near vertical changes in topography.

For the purposes of this report, an “aquifer” in unconsolidated materials (i.e., soil) is considered to be a geological deposit or formation that has high permeability relative to its surroundings and which readily transmits water to wells and springs. Bedrock aquifers have not been delineated in this report due to limited hydrogeological information and high variability in local permeability, though it is noted that in many cases wells drilled into the bedrock may yield a small groundwater supply suitable for domestic use. For the purposes of this report, an “aquitard” is a geological deposit or formation that has low permeability relative to its surroundings and which impedes or does not readily transmit groundwater to wells or springs.

Aquifers and hydrostratigraphy were interpreted by visualizing the associated datasets in 3D, cutting cross-sections, manipulating the model, and then by manually selecting and assigning various intervals to hydrostratigraphic units and aquifers. This method allowed the interpreter to assess and visualize the different types of hydrogeological data quickly and the ability to easily and continuously cut cross-sections to investigate areas of interest. Subsurface data, existing geological mapping, groundwater levels, and landform morphology were all considered when delineating the aquifer boundaries. Assumptions and notes regarding the delineation of the aquifers are documented in the associated aquifer description worksheets in Appendix 1.

Overview of Geology

The primary references that describe the background geological setting and Quaternary geology in the Watson Lake area are Lipovsky and McKenna (2005) and Mortensen and Murphy, 2005, which has been incorporated into the Yukon-wide bedrock geology compilation (Yukon Geological Survey, 2022). Witter (2022) also summarizes the structural geology of the area. Bedrock and surficial geology maps are provided in Figure 2 and Appendix 2.

Limited information on depth to bedrock in the valley bottoms is available; however, the morphology of the bedrock valleys is assumed to be U-shaped as a result of the glacial history. Seven primary bedrock units underlie the study area (Mortensen, and Murphy, 2005), listed in order from youngest to oldest; see Figure 2 and Appendix 2)):

- **Quaternary Selkirk Group mafic volcanics (TQS)** located in a small area on the western portion of the study area; consists of columnar jointed, vesicular to massive basalt flows.
- **Paleogene Ross Formation/Group (ITR3)** – western portion of the study area; consists of brown, thin-bedded, claystone, siltstone, shale and coal.
- **Upper Permian Simpson Lake Formation (PTrSL1) clastic sedimentary rocks** located on the eastern side of the study area; consists of polymictic conglomerate, sandstone, dark grey siltstone and shale.
- **Carboniferous-Permian Fortin Creek Group (CPSM1)** located in the eastern portion of the study area; consists of dark grey and black carbonaceous phyllite, chert and argillite.
- **Upper Mississippian-Pennsylvanian (Carboniferous) White Lake and King Arctic Formation (CK3) volcaniclastic rocks** located in the north western portion of the study area; consists of arkosic sandstone, basal polymictic metaconglomerate.
- **Upper Devonian-Lower Mississippian Earn Group Sedimentary Bedrock (DME1)** located on the eastern portion of the study area; consists of laminated slate, fine to medium-grained chert-quartz arenite and wacke.
- **Middle Silurian to Middle Devonian (SDA2)** located to the eastern portion of the study area; consists of dolostone, silty and sandy dolostone and limestone.

A number of N/S to NW/SE trending faults traverse the study area (e.g., Inconnu Fault), and the Tintina Fault runs in a NW/SE direction about 10 km south of the town centre.

Figure 2. Bedrock Geology - Watson Lake Area (YGS, 2022)

The depth to bedrock has been observed or inferred at six locations (i.e., wells Lot 18 Block 20; Watson Lake SWDF MW12-02; Watson Lake Campground well; Watson Lake CG well #1, Liard FN Well, Unit #37 and YOWN-2208) to the south and east of Watson Lake between approximately 610 masl and 695 masl. Overburden thicknesses at these wells varies from 6 m to 90 m. Between Mt. Maichen Ski Hill and Watson Lake, bedrock was intersected at a number of private domestic wells, wells with unknown purposes and at one public supply well (ie, wells Campbell Hwy Mile 5, lot 1-33; Both wells identified as Airport Road, Mile 4; Lot 1-45, 1-46; Lot 1-49; Campbell Hwy Mile 4, lot 1-59-1 and Ski Hill Watson Lake well) between 665 to 740 masl depending on the proximity to the lake. Overburden thicknesses at these wells varies from 1 m to 22 m. In the YOWN-2209 S/D stratigraphic borehole, bedrock was not encountered.

In 2005, surficial geological mapping and local-scale biophysical mapping was undertaken by Lipovsky and McKenna (2005; see Appendix 2) for the purpose of integrated resource management. A summary of the local glacial history based on this work is provided here.

"The Watson Lake map area has been glaciated many times during the Quaternary period (the last 2.65 million years; Hidy et al., 2013). Aside from scattered localities, evidence of the older glacial episodes are masked by deposits from the latest glaciation, which is known as the McConnell Glaciation (Lipovsky and McKenna, 2005). During this late Wisconsinan (~25,000-21,000 years ago) global advance of ice sheets, the Liard Lobe of the Cordilleran Ice Sheet flowed in an easterly direction out of the Cassiar Mountains and in a southeasterly direction out of the Pelly and Selwyn mountains, following the Tintina Trench / Liard Lowland. South of Watson Lake, ice flowed in a northeast to easterly direction in the lower Dease River and Lower Post areas (Ferbey et al., 2013).

A thick, gently undulating and rolling till plain streamlined with drumlins, flutings and grooves provides clear evidence of fast-flowing southeasterly to easterly ice flow over the Watson Lake region (Lipovsky and McKenna, 2005). At the height of the Last Glacial Maximum (LGM) or McConnell Glaciation (~18,000 years ago), ice in the Liard Lowland would have overtopped the highest uplands suggesting a minimum ice thickness of at least 500 m.

At the close of the McConnell Glaciation (~10,000 years ago) the Cordilleran Ice Sheet began to retreat toward source areas northwest and southwest of Watson Lake. During a period of re-advance and ice stagnation, the Liard River was dammed in the Lower Post area and an extensive glacial lake formed in the Liard River Valley. A thick sequence of fine-grained sediments were deposited at the bottom of this lake, which shrank and eventually drained as the ice sheet thinned and further retreated. Ongoing melt of more distal ice deposited outwash plains of sand and gravel up to 30 m thick above the lake sediments along the Liard River valley floor. Ice stagnation during deglaciation also left behind blocks of ice that became buried by outwash. Steep sided depressions and pitted, hummocky terrain were formed when the ice blocks subsequently melted out; Watson Lake itself may have formed from melt of a large stagnant block of ice. Glacial meltwater also carved deep meltwater channels through bedrock in various locations north and northeast of town."

Material descriptions and glacial history of the area generally suggest well-drained units form the bulk of surface sediments (glaciofluvial) with impermeable glaciolacustrine and till deposits at some depth. Glaciolacustrine deposits are inferred to be relatively laterally continuous. Thick impermeable till deposits are likely relatively continuous over low-elevation surfaces and thinner or even absent in the uplands area. Quaternary basalt units have been logged in the vicinity of the solid waste facility and in some locations along the Liard River valley; however, their full extent and distribution is not well understood.

YOWN Stratigraphic Boreholes

Following a review of the available data in the Study Area and a summary of the data gaps for aquifer mapping, the WRB advanced two stratigraphic boreholes in June 2022 in order to provide additional data points, increase the confidence in the stratigraphic correlations, and to further the understanding of the depositional environment.

YOWN-2208

Borehole YOWN-2208 is located along the east side of the Robert Campbell Highway at km 3. YOWN-2208 was subsequently completed as a monitoring well with a screened interval of 4.0 to 7.0 mbgs. At this location, bedrock was encountered at a shallow depth of 6.4 mbgs. The core from the stratigraphic borehole was logged by staff from the Yukon Geological Survey (YGS) and WSP. A simplified version of the borehole log, including the inferred depositional environments and hydraulic behavior is summarized in Table 3, below. Inferred hydraulic behavior is assessed by evaluating whether the material is permeable relative to its surroundings and would readily transmit groundwater.

Table 3: Simplified YOWN-2208 Borehole Log

Start Depth (m)	End Depth (m)	Material	Texture / Structure	Interpreted Depositional Environment	Inferred Hydraulic Behavior
0	1.5	*Not Logged - Unknown*			
1.5	*2.1*	*Sandy pebble gravel with trace silt*	*50% gravel, fine-coarse, angular to sub-angular; 50% sand, fine to coarse; poorly graded, max clast diameter of 10cm*	*Glaciofluvial*	*Permeable*
2.1	*2.4*	*Clayey silty fine to coarse sand and gravel*	*Gravel (60-70%) subrounded pebble (avg 2-4 cm; range 1-10 cm); medium sand (30%) with some muddier intervals*	*Glaciofluvial*	*Low Permeability*
2.4	*3.7*	*Loose sand and gravel*	*Poorly graded; 60% angular to rounded gravel, max size = 11 cm; 40% fine to coarse sand with trace silt*	*Glaciofluvial*	*Permeable*
3.7	*6.1*	*Compact gravelly sand, some silt (Sandy Till)*	*15-30% gravel, sub-angular to sub-rounded, fine to coarse (pebbles); fine well sorted sand*	*Basal Till*	*Permeable*
6.1	*6.4*	*Loose sand and gravel*	*Fine to coarse sand; fine to coarse sub-angular to sub-*	*Till*	*Permeable*

Start Depth (m)	End Depth (m)	Material	Texture / Structure	Interpreted Depositional Environment	Inferred Hydraulic Behavior
		with some silt	*rounded gravel, max clast diameter of 9cm*		
6.4	8.2	Weathered Bedrock			Low Permeability

YOWN-2209 S/D

Borehole YOWN-2209 S/D is located along the south side of Woodland Crescent in the vicinity of Hour Lake. YOWN-2209 S/D was subsequently completed as a monitoring well with a shallow (10.7 to 13.7 mbgs) and deep (47.2 to 50.3 mbgs) screened interval (YOWN-2209 S/D). As one of the deepest boreholes in the study area, this location provides important detailed information on the stratigraphy at depth and a better understand of the geological history of the area. The core from the stratigraphic borehole was logged in detail by staff from the YGS and WSP. A simplified version of the borehole log, including the inferred depositional environments and hydraulic behavior is summarized in Table 4, below.

Table 4: Simplified YOWN-2209 S/D Borehole Log

Start Depth (m)	End Depth (m)	Material	Texture / Structure	Interpreted Depositional Environment	Inferred Hydraulic Behavior
0	3	Not Logged - Unknown			
3	15.2	Gravelly SAND	*Medium to coarse; subround to angular gravel (30% gravel), max clasts diameter of 8 cm at 9.4 m; loose; intervals of coarser and finer material – 4.0 to 4.6 m, 4.8 to 6.4 m, 7.3 to 7.9 m and 9.7 to 11.5 fine sand, 12.5 to 13.4 m coarse gravel*	*Glaciofluvial*	Permeable
15.2	20.4	SAND and GRAVEL	*Fine to medium sand with some gravel (up to 15% gravel); 15.2 -16.2 m sand; 16.2-17.1 m approx. 15 to 20% pebble gravel*	Deltaic (Glaciolacustrine)	Permeable

Start Depth (m)	End Depth (m)	Material	Texture / Structure	Interpreted Depositional Environment	Inferred Hydraulic Behavior
20.4	23.2	Fine SAND	Poorly graded/well sorted, organic/wood fragments up to 1 cm at 21 m and 22.9 m; no clasts	Deltaic (Glaciolacustrine)	Permeable
23.2	28.3	NO RECOVERY			
28.3	29.3	Medium SAND	Clean sand from 28.3-29.3 m	Deltaic (Glaciolacustrine)	Permeable
29.3	41.1	NO RECOVERY			
41.1	43	Very fine SAND with trace SILT	Compact	Glaciolacustrine	Low Permeability
43	47.5	Silty CLAY with some sand near top	Water content greater than plastic limit; one pebble dropstone @ 46.3 m	Distal Glaciolacustrine Lake Bottom	Low Permeability
47.5	48.5	Coarse GRAVEL with some SAND and SILT, trace CLAY	~70% angular to subrounded gravel, up to 7cm, trace plastic fines,	Deltaic (Glaciolacustrine) (Deltaic flood event?)	Permeable
48.5	50	Fine to coarse SAND and GRAVEL	Subangular to rounded sand and gravel; pebble to cobble max diameter of 8 cm	Deltaic (Glaciolacustrine)/ Shifting Channel	Permeable
50	56.7	SAND and trace GRAVEL	Fine to medium clean/well sorted, one inferred cobble just above 56.7 m; 53.0-53.3 m: coarse sand and some gravel with trace plastic fines	Deltaic (Glaciolacustrine)	Permeable
56.7	58.8	CLAYEY SAND matrix with angular clasts (inferred boulders)	very dark grey, very dense, 70% clayey sand matrix, angular to subrounded clasts, inferred boulders (shattered/angular clasts); some clasts oxidized	Basal Till	Low Permeability

The geological interpretation of the YOWN-2208 and YOWN-2209 S/D stratigraphic boreholes provides important insight into depositional processes and geological controls on groundwater movement. Furthermore, to confirm the composition of the permeable units screened by YOWN-2208 and YOWN-2209 S/D as well as the confining clay unit that separates the nested well, four soil samples were submitted to WSP's laboratory for grain size and hydrometer testing. A summary of the grain size analysis results is presented in Table 5 below. Full grain size analysis results are provided in Appendix 3.

Table 5: Summary of Grain Size Analysis

Grain Size	Percentage Retained of Sample			
	YOWN-2208	YOWN-2209 S	YOWN-2209 D	
	Sample Depth 3.96 – 6.10 m	Sample Depth 11.58 – 13.72 m	Sample Depth 42.98 – 47.55 m	Sample Depth 48.46 – 49.99 m
Gravel	28.5%	37.6%	0.0%	31.4%
Sand	46.0%	60.2%	3.2%	63.2%
Fines (Silt and Clay)	25.5%	2.2%	96.8%	5.4%

The bedrock valleys are expected to be low permeability and to control the distribution and thickness of unconsolidated materials within the Study Area. Bedrock was intersected at 6.4 mgbs in YOWN-2208 which is located just north of a hill underlain by shallow bedrock; bedrock was not intersected YOWN-2209 S/D.

Based on stratigraphy encountered at YOWN-2208, the stratigraphy at other boreholes in the areas and the glacial history of the region, basal till is inferred to directly overlie bedrock throughout the Watson Lake area. At YOWN-2208, till consisted of a compact gravelly sand with some silt underlain by a thin layer of compact gravelly sand with subangular to subrounded gravel and some silt to loose sand and angular gravel with some silt. YOWN-2208 is screened within this till unit. Grain size analysis of the screened interval indicates materials consisting predominantly of fine to coarse sand (46.0%) and gravel (28.5%). At YOWN-2209 S/D the basal till unit encountered consisted of 2 m of a very dense clayey sand matrix supported diamict with angular clasts (inferred boulder); the base of this unit was not determined, and the unit is likely much thicker than 2 m. The differences between the till in the two holes reflects the inherently variable nature of morainal deposits, as described in the surficial geology mapping of the area.

Directly overlying the basal till in the YOWN-2209 D stratigraphic borehole, from 47.5 – 56.7 mbgs, is approximately 8 m of primarily sand with some gravel in the upper 2 m. The sands were deposited in a glacial lake deltaic environment, and it is uncertain whether the coarser gravel deposits are more extensively distributed throughout the valley or are related to a localized meltwater channel system whose extent would be relatively limited. Incised meltwater channels can be seen at surface to the northwest of Second Wye Lake approximately 2.5 km from the YWON-2209 S/D. YOWN-2209 D is screened within this unit. Grain size analysis of the screened interval indicates materials consisting predominantly sand (63.2%) and gravel (31.4%) with less than 5.5% of fines from a depth of 48.46 to 49.99 m. Grain size analysis from sample collected right above the screened interval from 42.98 to 47.55 m indicates material consisting predominantly of fines (96.8%). None of the other boreholes in the area have intersected this permeable unit.

A silty clay unit was observed from 43 and 47.5 mbgs, above the lowest sand and gravel unit in the YOWN-2209 S/D borehole. This unit is interpreted to be distal glacial lake bottom sediment that covered much of the region. Directly overlying the glacial lake bottom deposits, from 15.2 to 43 mbgs, is an approximately 28 m section primarily comprising very fine to medium sand, with some gravel in the upper 5 m. This interval is inferred to be associated with a glacial lake deltaic depositional environment. Two large sections of core (29.3 to 41.1 mbgs and 23.2 to 28.3 mbgs) were lost from this inferred delta package during the drilling process. Based on notes taken at the time of drilling, these sections were inferred to consist mainly of saturated fine grained flowing sands. Sediments in the deltaic package generally coarsen upwards from fine/medium sand closer to the bottom to poorly graded coarse sand with some wood fragments (20.4-23.2 mbgs) and up to 20% gravel from 15.2-20.3 mbgs. This coarsening is interpreted to reflect a transition from a lower energy deep water lake environment to a higher energy or shallow water environment. At both YOWN-2208 and YOWN-2209 S/D, the upper most unit consists of coarse-grained sand and gravel deposits interpreted to be of glaciofluvial origin. These deposits were intersected from surface to a depth 3.7 mbgs at YOWN-2208 and from 3.0-15.2 mbgs at YOWN-2209 S/D (no core was recovered from 0.0 – 3.0 m). YOWN-2209 S is screened within this unit. Grain size analysis of the screened unit indicates materials consisting predominantly of sand (60.2%) and gravel (37.6%)

Hydrogeology

The hydrostratigraphy of an area is a simplified representation of the geology where the various geological units are grouped and classified according to the hydraulic characteristics and expected hydrogeological behaviour (i.e., aquifer or aquitard). Classification of hydrostratigraphic units as aquifers or aquitards is completed on the basis of their relative hydraulic conductivity (based on texture) to other units and ability of the hydrostratigraphic unit to provide a useable source of groundwater and yield. Table 6 presents a summary of the hydrostratigraphic units for the Study Area with detailed descriptions provided in the subheadings below.

Table 6: Inferred Hydrostratigraphic Units and Classifications

Hydrostratigraphic Unit	Thickness (m)	Elevation Range (masl)	Interpreted Depositional Environment	Hydrostratigraphic Classification
Fan Deposits[a]	35	645 - 685	Glaciofluvial Fan/Delta	Unconfined Aquifer
Glaciofluvial Deposits[a]	20 – 40	650 - 740	Glaciofluvial	Unconfined Aquifer and Potential Unconfined Aquifer (in Liard River Valley)
Deltaic Package[a]	20 - 40	635 -675	Glaciolacustrine Delta	Partially Confined Aquifer
Glaciolacustrine Deposits[a]	< 15	630 - 645	Glacial Lake Bottom	Aquitard
Till[a]	Up to 65	550 - 845	Glacial	Local Aquitard / Aquifer
Deep Sands and Gravel[a]	10	635 - 645	Deltaic or Glacial Meltwater Channels	Potential Confined Aquifer
Deep Glacial Outwash Sands and Gravel[a]	20 - 40	585 - 635	Glacial Outwash	Potential Confined Aquifer

Hydrostratigraphic Unit	Thickness (m)	Elevation Range (masl)	Interpreted Depositional Environment	Hydrostratigraphic Classification
Bedrock	-	< 750	N/A	Local Aquitard / Aquifer

Footnote
(a): Glacial Deposits (fluvial, lacustrine and till) units are assumed to be McConnell in age

Two unconfined aquifers and one partially confined aquifer were identified and delineated as part of the hydrostratigraphic interpretation. Three potential aquifers are preliminarily identified in this report and are associated with the Deep Sands and Gravel, Deep Glacial Outwash Sands and Gravel, and the Glaciofluvial Deposits in the Liard River Valley. In the case of the Deep Sands and Gravel hydrostratigraphic unit, this deposit was intersected only by the newly drilled YOWN 2209 D borehole (from 47.5- 56.7 depth) and insufficient evidence is available to definitively map this unit as an aquifer. For the Deep Glacial Outwash Sands and Gravel hydrostratigraphic unit and the portion of the Glaciofluvial Deposits in the Liard River Valley, these permeable units were intersected by environmental boreholes, test holes, and geotechnical boreholes on the south side of the inferred bedrock ridge in the Liard River Valley. At this time, there are no wells that are currently utilizing these deposits for water supply purposes and therefore insufficient evidence is present at this time to classify these permeable deposits as aquifers.

The aquifers, potential aquifers, and other hydrostratigraphic units are described in the subsections below with aquifer description sheets for the proven aquifers provided in Appendix 1. Hydrostratigraphic cross-sections showing the locations of the hydrostratigraphic units relative to one another are provided in Appendix 4, and an Aquifer Summary Table in the format of the BC Aquifer Mapping and Classification System (Bernardinucci and Ronneseth, 2002) is provided in Appendix 5. Aquifer shapefiles are provided in Appendix 6, aquifer-well correlations are provided in Appendix 7, and a table of the interpreted hydrostratigraphic picks by well record is provided in Appendix 8.

Bedrock

The bedrock valleys are the main controls on the distribution and extent of the unconsolidated deposits in the study area. As the majority of the population in the study area reside in the valleys, where the depth to bedrock is relatively large and the unconsolidated deposits are thicker, a limited number of water wells have been completed in bedrock and the hydrogeological understanding of the bedrock is relatively low. As described in Section 3, there are seven bedrock units as described by Yukon Geological Survey (2022) and Mortensen and Murphy (2005) that underlie the study area.

In general, as the hydraulic conductivity of the bedrock is expected to be low in comparison to the unconsolidated sediments, bedrock is classified as an aquitard. Where appreciable groundwater flow within the bedrock occurs, it is expected to be controlled primarily by faults and fractures. Despite the classification as an aquitard, low hydraulic conductivity shallow bedrock is often exploited for small scale domestic water supply purposes. It is expected that the bedrock hydrostratigraphic unit would often be capable of providing a private domestic water supply, however the potential groundwater quality is unknown. Wells along the north-eastern portion of Watson Lake are screened in Simpson Lake Formation sedimentary bedrock for domestic water supply purposes. A formal bedrock aquifer has not been delineated, but additional development in this area may utilize the bedrock in this area for domestic purposes.

Till

The Till hydrostratigraphic unit is associated with the McConnell Glaciation and is generally observed as a thin deposit in upland areas where that directly overlies the bedrock at higher elevations. Thicker deposits of dense gravelly sandy loam basal or lodgement till are commonly observed in the Watson Lake area in the form of fluted landforms and flat-lying plains with drumlins. Fluted landforms consist of up to 60 m of morainal materials ranging from permeable sandy gravel layers to low permeability matrix-supported fine grained clay tills. Groundwater wells in the area are primarily localized to the valley bottom and information about the till deposits is limited. The Till may have localized areas of high permeability, particularly within looser sandy gravel ablation till; however, it is anticipated that these portions would be of limited extent, and well yields would likely be limited.

The Till was intersected by the stratigraphic borehole YOWN-2209 S/D at a depth of 56.7 m (~633 masl) in the base of the valley. At this location, the unit is described as a dark grey, very dense clayey sand with angular to subrounded clasts (including an inferred boulder). The unit was also intersected by YOWN-2208 where the deposit ranges from a loose sand matrix with some silt and angular gravel to a compact gravelly sand with some silt.

Deep Glacial Outwash Sands and Gravel (Potential Aquifer)

The Deep Glacial Outwash Sands and Gravel unit is a confined unit inferred to overlie the till layer to the southwest of Watson Lake between the Solid Waste Facility and the Liard River Valley. Eight environmental wells were drilled at an industrial area across the Alaska Highway from the Solid Waste Facility. The four deep wells intersected a saturated sand unit overlying a saturated gravel unit at an elevation of 640 to 635 masl. This permeable unit which generally fines upwards, is inferred to be associated with glacial outwash during glacial retreat and is anticipated to be laterally extensive to the edge of the Liard River Valley. Water levels are generally between 620-635 masl at the environmental wells. No other wells are present in the area and no water supply wells are currently screened in this unit. Additional deep boreholes/wells and estimates of yields would be needed to confirm the viability of the Glacial Outwash Sands and Gravel unit as an aquifer. The possible extent of the Deep Glacial Outwash Sands and Gravel hydrostratigraphic unit is presented in Figure 3.

This hydrostratigraphic unit is also herein referred to as the Potential Deep Glacial Outwash Sands and Gravel Aquifer.

Deep Sands and Gravel (Potential Aquifer)

The Deep Sands and Gravel hydrostratigraphic unit is a confined unit overlying a low permeability basal till layer (inferred to overlie bedrock) in the deepest portions of the bedrock valleys at the southeast of the study area. In stratigraphic borehole YOWN-2209 S/D, the Deep Sands and Gravel unit consists of a fine to medium sand with trace gravel overlain by a coarse sand and gravel layer. The unit is overlain by a silty clay with fine sand unit inferred to be glacial lake bottom sediments observed at approximately 43 mbgs.

The depositional environment of the coarse sand and gravel that comprise this potential aquifer are inferred to be related to a deltaic flood event and/or a shifting meltwater channel. Based on these differing potential depositional environments, the deposits may be widely distributed throughout the valley and constrained by the bedrock valley walls, or may be confined to narrower meltwater channels within the larger valley. One deep water well (201020068) was drilled to a similar depth at YOWN-2209 S/D but did not intersect the permeable unit and was completed in bedrock. This well is located along the margins of the valley and offset from the meltwater channels visible near surface at Second Wye Lake. At this time, the unit has been classified as an inferred or a potential aquifer because only one well intersected the unit, no water supply wells are present in the unit, and no estimate of yield has been obtained at this time. Additional deep boreholes/wells would be needed in the area to provide more information on the extents of the Deep Sands and Gravel deposit prior to it being classified as an aquifer. The possible extent of the Deep Sands and Gravel hydrostratigraphic unit is presented in Figure 3.The YOWN-2209 D monitoring well was installed in the Deep Sands and Gravel unit with a screened interval of approximately 47.2 – 50.3 mbgs.

This hydrostratigraphic unit is also herein referred to as the Potential Deep Sands and Gravel Aquifer.

Glaciolacustrine Deposits (Watson Lake Aquitard)

The Glaciolacustrine Deposits hydrostratigraphic unit directly overlies the Potential Deep Sands and Gravel Aquifer and the Potential Deep Glacial Outwash Sands and Gravel Aquifer within the bedrock valleys or, where these units are not present, the aquitard is inferred to directly overlie the till. The aquitard is interpreted to be comprised of clay and silt with some fine sand and is expected to have low hydraulic conductivity in relation to the overlying and underlying hydrostratigraphic units. The clay/silt aquitard is interpreted to be associated with a glacial lake that formed in the area and is assumed to be distributed relatively contiguously across the low-lying portions (valleys) of the Study Area, confining the Potential Deep Sands and Gravel Aquifer and the Potential Deep Glacial Outwash Sands and Gravel Aquifer.

In the YOWN-2209 S/D borehole log, the thickness of the Watson Lake Aquitard hydrostratigraphic unit was observed to be approximately 4.5 m and at Well ID 201020068 it is interpreted to be up to 10 m thick.

This hydrostratigraphic unit is herein referred to as the Watson Lake Aquitard.

Deltaic Package (Deltaic Package Aquifer)

The Deltaic Package hydrostratigraphic unit is interpreted to be extensive throughout the study area to the east of Watson Lake. The unit is inferred to be intersected by a number of wells at the east end of Watson Lake, in the vicinity of Wye Lake, at YOWN stratigraphic borehole YOWN-2209 S/D, and two wells further to the southeast. The Deltaic Package hydrostratigraphic unit is a primary source for water supply wells in the Town of Watson Lake.

At YOWN2209 S/D, the unit is present directly above the inferred fine grained glacial lake bottom deposits (Watson Lake Aquitard). The unit consists of 2 m of very fine sand at the base and is inferred to transition into a clean medium sand around 661 masl (there was no core recovery between 649 to 661 masl). A 3 m interval of fine-grained sand with rare wood fragments was intersected at an elevation of 660 to 670 masl. Wood and organic fragments are also observed in this finer grained layer at similar elevation in well logs at the eastern edge of Watson Lake.

The upper portion of the unit is generally coarser in its eastern extents and consists of medium sand and gravel and is generally finer grained in the upper portions at the edge of Watson Lake. The layers of finer grained and coarser grained material represent periods of variable energy meltwater flow and sediment input into the glacial lake during deglaciation. The inferred extent of the Deltaic Package hydrostratigraphic unit is presented in Figure 4.

This hydrostratigraphic unit is herein referred to as the Deltaic Package Aquifer.

Glaciofluvial Deposits (Glaciofluvial Aquifer)

The Glaciofluvial Deposits hydrostratigraphic unit is an unconfined sand and gravel unit extending from the eastern side of Watson Lake to past the YOWN -2209 S/D well to the southeast. The unit is constrained to the mapped glaciofluvial deposits in the valley. Lithological descriptors indicate that the deposits are predominantly coarse sand and gravel with minor amounts of silt. At Well ID 201020130, layers of peat are noted near the base of the coarse-grained unit around 16 mbgs. The Glaciofluvial Aquifer directly overlies the Deltaic Package Aquifer. The materials of the hydrostratigraphic unit are generally inferred to be associated with glaciofluvial outwash deposits and are utilized by a number of domestic water wells and small public supply wells throughout the Study Area. The inferred extent of the Glaciofluvial Deposits hydrostratigraphic unit is presented in Figure 5.

This hydrostratigraphic unit is herein referred to as the Glaciofluvial Aquifer.

Glaciofluvial Deposits in Liard River Valley (Potential Aquifer)

The glaciofluvial deposit in the Liard River Valley hydrostratigraphic unit is an unconfined unit located in Liard River Valley to the southwest of the Town of Watson Lake between the Solid Waste Facility and the Liard River Valley. This unit is inferred to have the same glaciofluvial outwash depositional environment as the proven Glaciofluvial Aquifer to the north. The glaciofluvial deposits at surface are mapped to the edge of the Liard River Valley, consistent with the surficial geology mapping. The eight environmental wells drilled at an industrial area across the Alaska Highway from the Solid Waste Facility are inferred to have intersected the unit from surface to a depth of approximately 40 mbgs. The material is described as dry to moist sand and gravel with one section of wet sand and gravel noted between 660 to 665 masl in boreholes 980000477, 980000480, 980000482. Three shallow wells were completed in this unit with water levels measured at approximately 662 masl. The saturated unit was only intersected by three of the environmental wells and no water supply wells are currently screened in this unit. The unit is inferred to have variable saturation (as seen in the environmental holes) and additional boreholes/wells and estimates of yields would be needed to confirm the viability of this portion of the Glaciofluvial Deposits as an aquifer. The possible extent of the glaciofluvial deposit in the Liard River Valley hydrostratigraphic unit is presented in Figure 3.

This hydrostratigraphic unit is herein referred to as the Potential Glaciofluvial Aquifer (Liard River Valley).

Fan Deposits (Fan Aquifer)

The Fan Deposits hydrostratigraphic unit is comprised of a glaciofluvial fan deposit located along the northwestern portion of Watson Lake in the vicinity of the Watson Lake Airport. The hydrostratigraphic unit consists of fine to coarse sand and gravel deposits extending from surface to a depth of 35 mbgs. The unit is inferred to overlie the till and is constrained by Watson Lake to the south. The unit has a limited number of users and is primarily associated with the use of facilities and activities at the Airport. The inferred extent of the Fan Deposits hydrostratigraphic unit is presented in Figure 5.

This hydrostratigraphic unit is herein referred to as the Fan Aquifer.

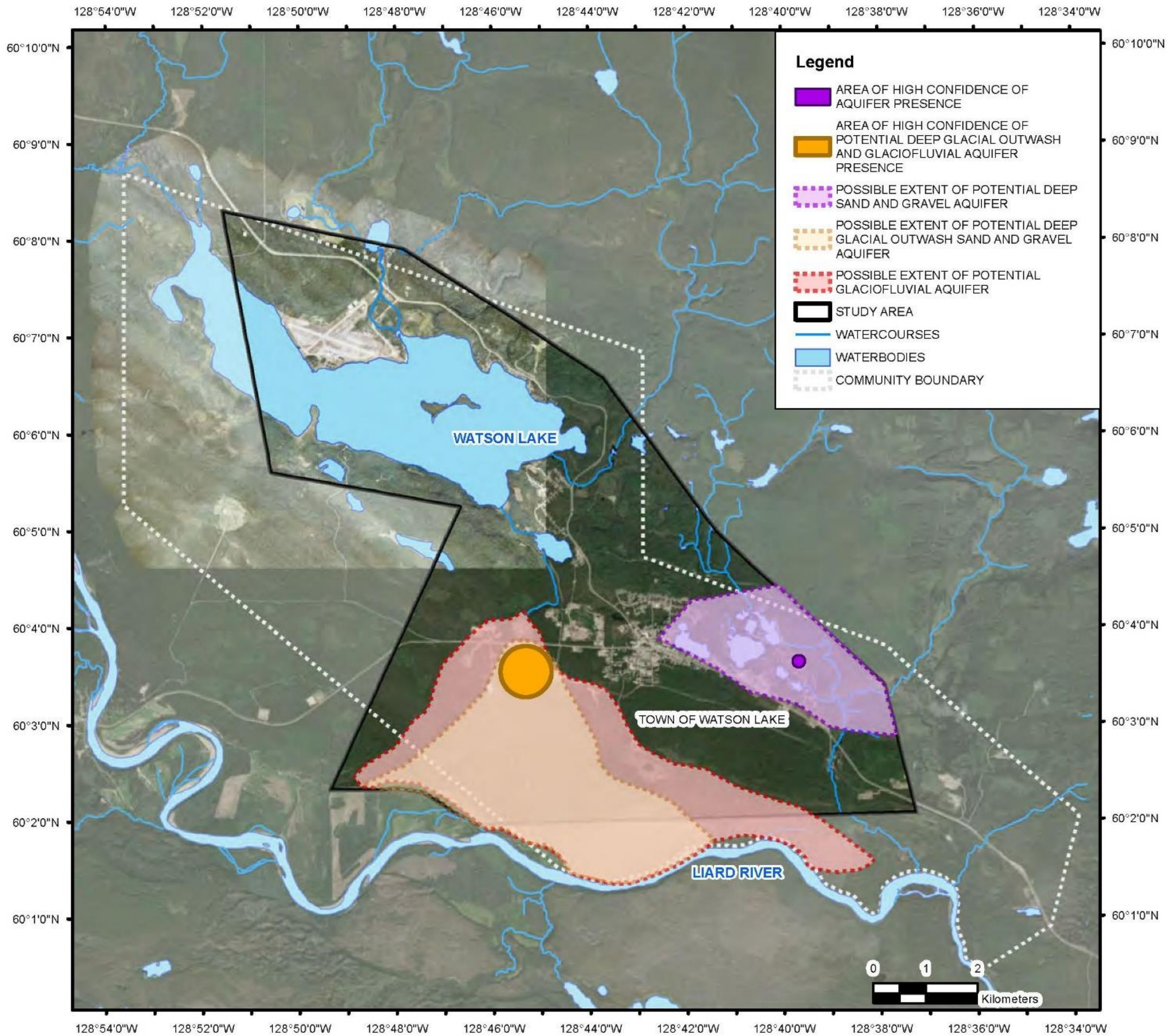


Figure 3: Possible Extent of the Potential Deep Sands and Gravel Aquifer, Potential Deep Glacial Outwash Sands and Gravel Aquifer and Potential Glaciofluvial Aquifer (Liard River Valley)

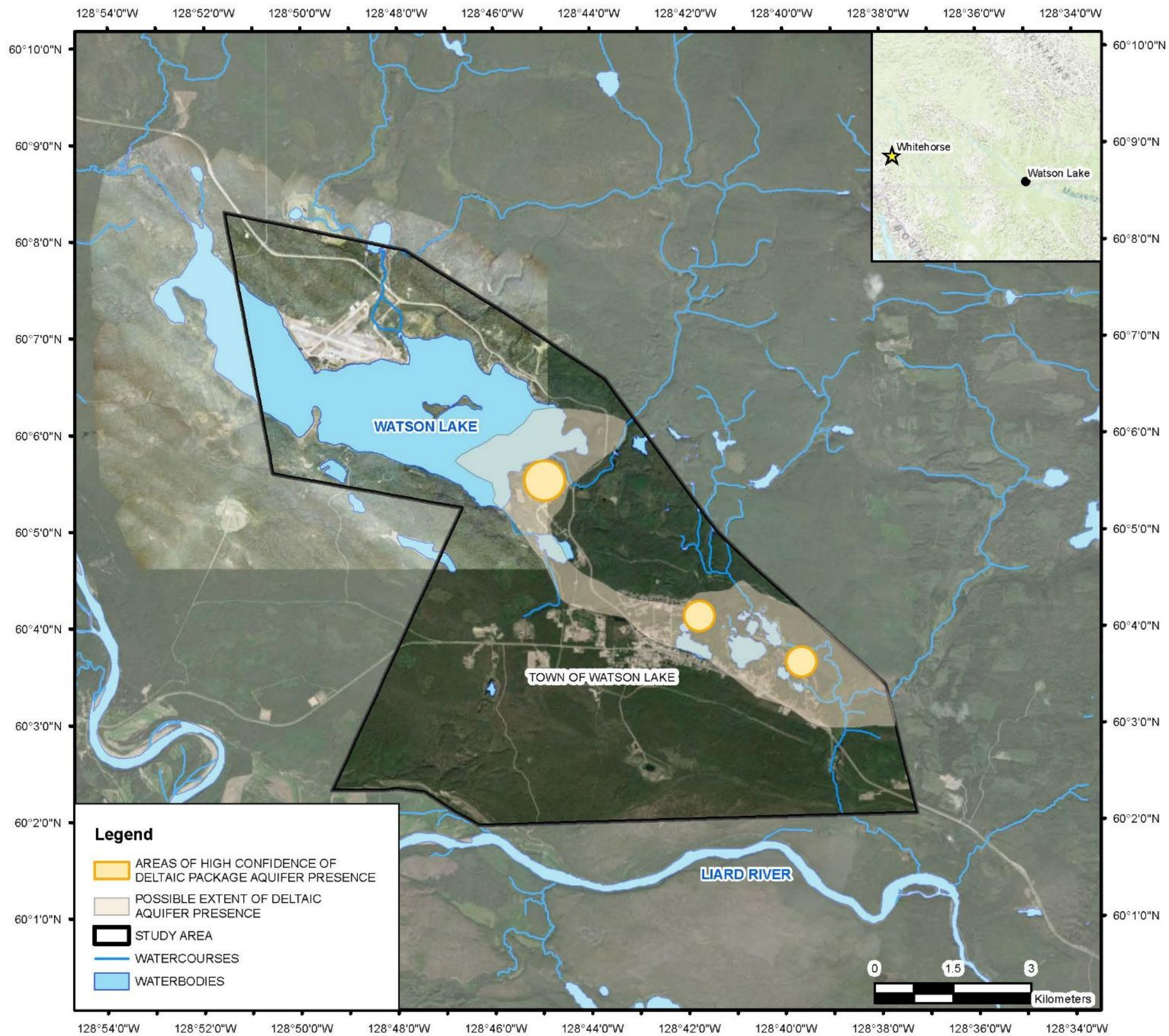


Figure 4: Inferred Extent of Deltaic Package Aquifer

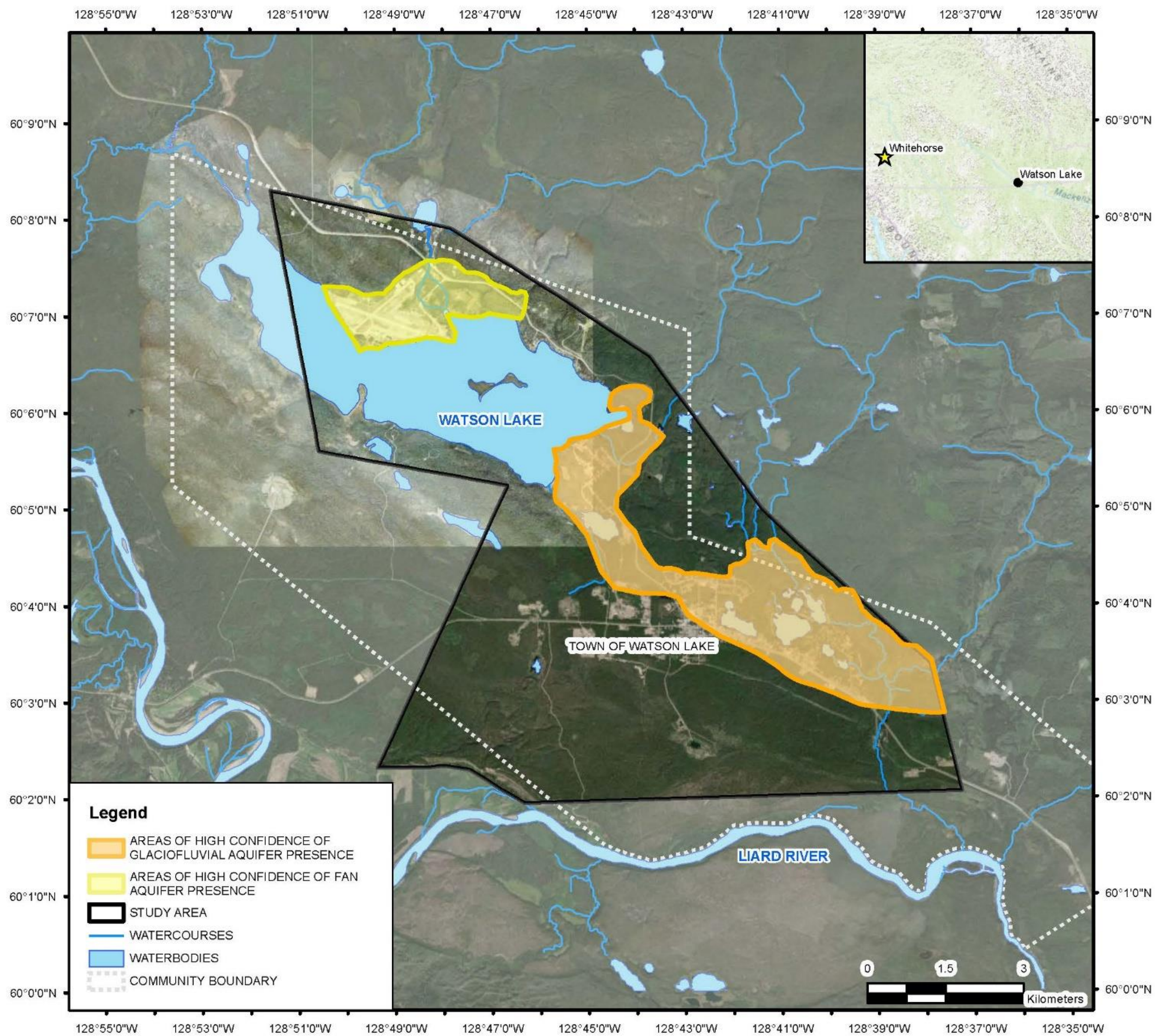


Figure 5: Inferred Extent of Glaciofluvial and Fan Aquifers

Data gaps and uncertainty

Watson Lake, YT

As part of a data gap assessment for the project, WSP reviewed available data for the Study Area and prepared a presentation on the Data Coverage and Gap Analysis for the Watson Lake area for YG WRB, LFN, DKI, Town of Watson Lake, YGS, GSC and Yukon University (presentation provided on 09 August 2022). The primary data gaps identified during this assessment included:

- A limited number of deep boreholes (> 50 m)
- Uncertainty associated with the lithological descriptions included in the deeper boreholes from the Yukon Water Well Registry (descriptions are from well drillers and not geologists)
- Lack of spatial distribution of deep boreholes which would allow for stratigraphic correlation of potential deeper aquifers or confining units at depth (primarily below ~665 masl)
- Limited or inconsistent description/presence of possible confining units or aquitards (till, clay, silt) at depth
- Limited information outside of the populated area to delineate lateral extent of potential aquifers
- Limited information from borehole logs on the bedrock contacts in the valley

Based on the results of this data gap assessment, the YG WRB drilled the YOWN-2208 and YOWN-2209 S/D stratigraphic boreholes to address some of the data gaps and uncertainties that were identified. The YOWN-2208 and YOWN-2209 S/D stratigraphic boreholes were extremely beneficial to the project as they provided the following:

- A deep borehole in a strategically important area that reached the top of bedrock
- High quality sediment descriptions, logged and reviewed with local experts at the YGS, that could be used to correlate lithology descriptions from other water well records and boreholes
- Information on the geological history and depositional environment, which allowed greater confidence in extrapolating aquifer boundaries in areas of uncertainty and limited information
- Monitoring wells that provide the opportunity for ongoing groundwater monitoring at these locations

Outstanding data gaps include the following:

- Other than the YOWN-2209 S/D stratigraphic borehole, limited information on the deeper hydrostratigraphic units (i.e., Potential Deep Sands and Gravel Aquifer and Watson Lake Aquitard) exists to confirm lateral continuity of the units and the hydrostratigraphic interpretation
- Limited subsurface information on the south side of the bedrock ridge to the south of the Solid Waste Facility.

Upper Liard, YT

As part of the data gap assessment for the Watson Lake area, WSP was asked to review information for the Community of Upper Liard (Upper Liard), located southwest of Watson Lake. Groundwater wells in the area are used as private domestic wells, public supply wells, and environmental monitoring wells. The YWWR contains 13 well locations, 10 of which have known well depths and lithological well logs. Drilling logs for groundwater wells range in depth from approximately 13 m to 29 m. Installation depths for well screens range from 11 m to 28 m, with an average installation depth of between 11 and 14 metres below ground surface and an average screened interval of 1.2 m. Lithology descriptions provided on well logs generally include grain-size descriptions such as sand, silty sand and sand with pebbles.

In addition to the water well records, eight deep boreholes (up to 160 m deep) were drilled in the 1970s for coal investigation purposes. These boreholes are primarily focused in the areas just west of Upper Liard on the western edge of the Tintina Trench. Limited descriptions regarding saturation are available in these borehole logs. Lithological descriptions for the locations include intervals of clay and silt interbedded with coal, sand, sand and gravel and bedrock. These coal investigation holes extend to an elevation of 470 masl, considerably deeper than the water wells in the area which terminate at an elevation between 595 and 615 masl.

Figure 6 presents the locations of subsurface data that indicates relative drilled depth and whether lithology information is available.

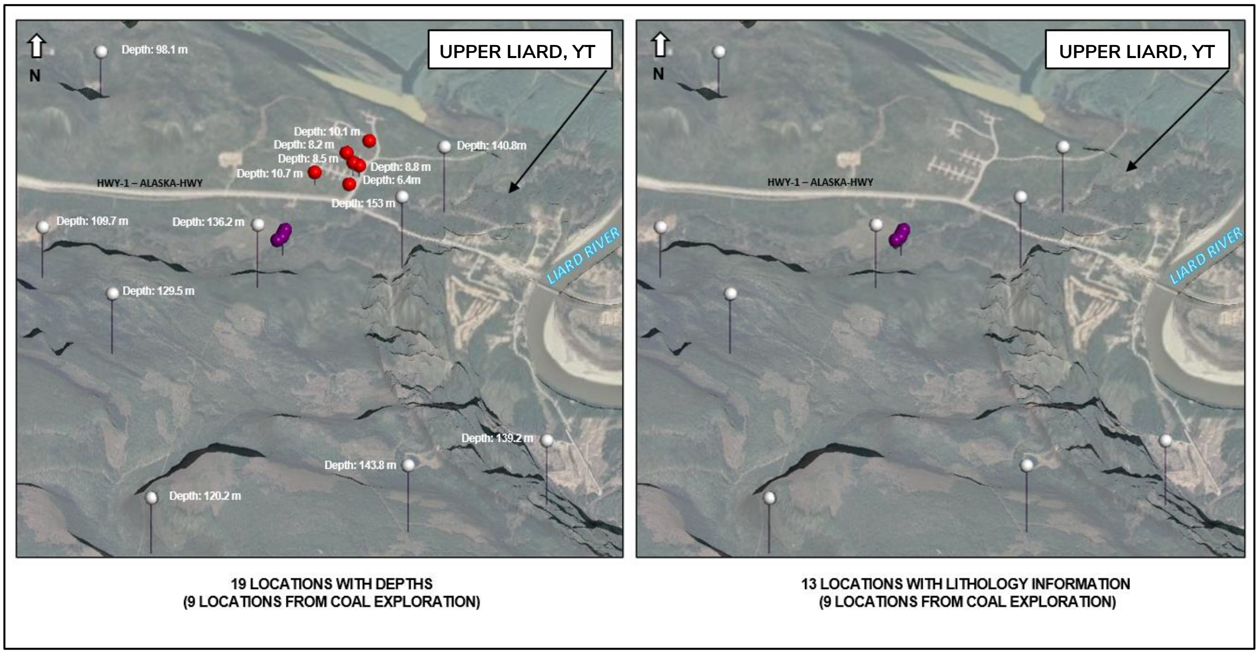


Figure 6: Location of wells and Distribution of Downhole Information in Upper Liard, YT

Figure 7 presents a cross-section cut through the monitoring wells and Liard Coal boreholes with lithology data. Raw lithologies have been grouped to facilitate correlation of similar intervals across boreholes.

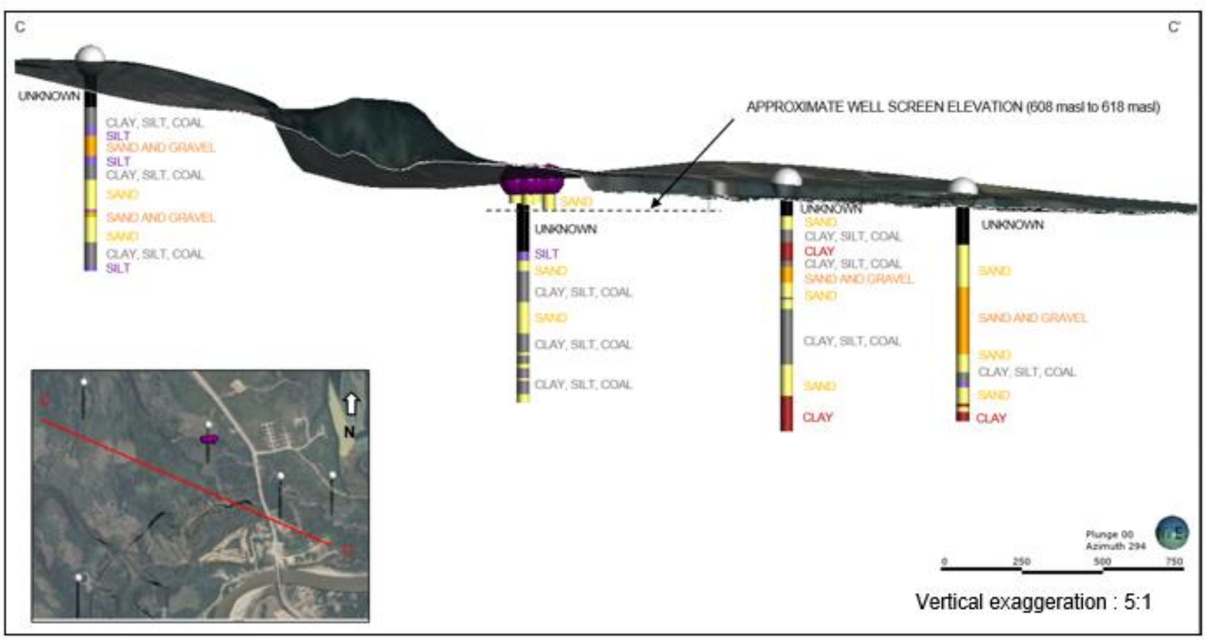


Figure 7: Cross-Section C-C' of Preliminary Lithological Groupings for Downhole Lithologies in Upper Liard, YT

Based on a review of available information, there is limited data available for aquifer delineation purposes in the Upper Liard area. Lithology for only four water wells are available and drill depths are all less than 30 m. Deep subsurface investigation from the deep coal investigation boreholes are generally distributed further from town in and around the hills and fluvial plain and do not have information about degree of saturation of the sediments or whether groundwater was encountered. Information from these boreholes can be useful for determining intervals of coarse permeable material that may have the potential to be water bearing; however, without water wells installed in a permeable unit, the presence of water cannot be confirmed.

The water wells in the area are all between 15 to 30 m depth located close to the fluvial plain and these wells appear to be screened in an unconfined unit. The stratigraphy of the coal investigation boreholes suggests that the presence of a number of silt/clay layers (possible aquitard) below the depths of the current water wells at an elevation of approximately 580-560 masl and 510-520 masl. Deeper well records would be needed to determine if a deeper confined aquifer does exist below these finer units. For the purposes of delineating the extent of the unconfined aquifer currently being utilized by the community, the lithology for additional water supply, domestic or environmental wells would be needed.

Lower Post, BC

In addition to the data review for the community of Upper Liard, YT, WSP was also asked to review available data for aquifer mapping purposes for the community of Lower Post, BC located just south of the Yukon – British Columbia border.

Groundwater wells in the area are used as private domestic wells, public supply wells, and environmental monitoring wells. The YWWR only contains 3 well locations as Lower Post is located outside of the Yukon in northern BC; however, additional well locations are available through the BC provincial water well database (GWELLS, 2021). In total, 14 well locations were identified in the BC database, with only five locations having lithological well records.

The Daylu Dena Council, via DKI, provided the location for 27 known wells (10 not included in the WELLS or YWWR databases); however, no additional lithological logs or well depths were available.

Figure 8 presents the distribution of water wells in Lower Post while Figure 9 presents the locations of subsurface data with known drilled depth and whether lithology information is available.

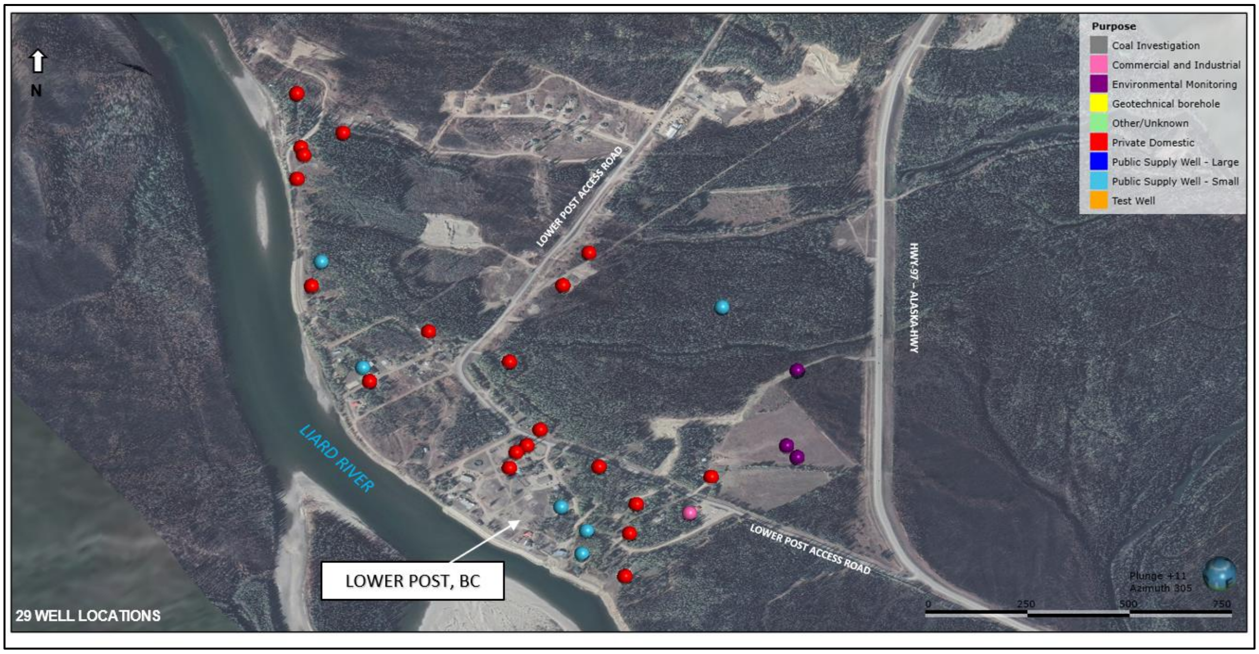


Figure 8: Locations of Wells in Lower Post, BC

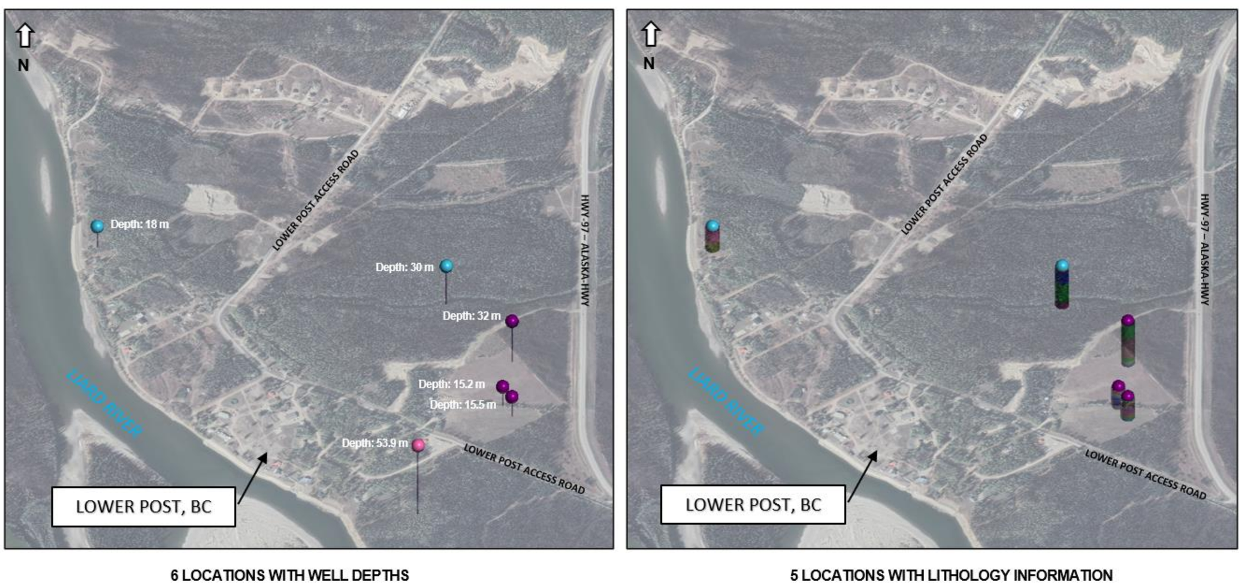


Figure 9: Distribution of Downhole Information in Lower Post, BC

Figure 10 presents a cross-section cut through the water wells with lithology data. Raw lithologies have been grouped to facilitate correlation of similar intervals across boreholes.

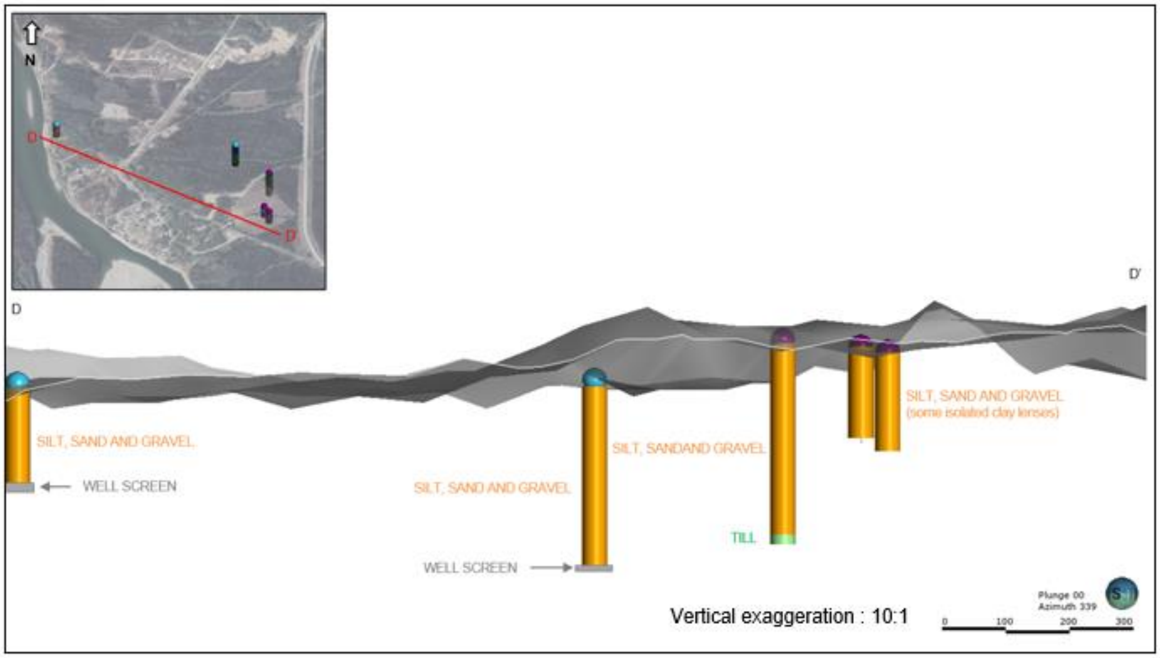


Figure 10: Cross-Section D-D' of Preliminary Lithological Groupings for Downhole Lithologies in Lower Post, BC

Groundwater wells in Lower Post appear to be screened in a relatively thick (up to 30 m) unconfined silty sand and gravel unit. A well log for an environmental well indicates the presence of a till layer at an elevation of ~557 masl. The two water supply wells in the areas with lithology data were completed before the base of the silty sand and gravel unit was intersected which suggests that sufficient water is present in this unconfined unit for relatively small water supply purposes. Yields for the two wells are reported as 235 and 280 L/min at the time of drilling (likely estimated using air development) and higher yields may be possible following well development and utilization of a well pump. A deeper well (~54 m) located at the gas station has a smaller reported yield of 57 L/min; however, there are no lithology well logs available to confirm the unit in which this well was screened.

Similar to the available data in Upper Liard, limited lithological information is available for the purposes of delineating the unconfined aquifer; however, the distribution of domestic water supply wells is more spread out than in the case of Upper Liard. Domestic water wells typically terminate where water is intersected, unless there is a known reason to drill more deeply (such as a water quality concern or low yield in an upper aquifer). Based this information, the unconfined aquifer unit utilized by the two water supply wells and intersected by the environmental wells could be inferred to extend across the area where water wells are present; however, at this time, in the absence of additional lithology information, an aquifer has not been formally delineated for Lower Post.

Conclusions and Recommendations

Three proven aquifers have been delineated in the Watson Lake area:

1. The Fan Aquifer is an unconfined sand and gravel aquifer constrained to the fan deposit in the vicinity of the airport.
2. The Glaciofluvial Aquifer is constrained to the glaciofluvial sands and gravels in the valley southeast of Watson Lake.
3. The Deltaic Package Aquifer is a partially confined sand (some gravel) aquifer that underlies the unconfined Glaciofluvial Aquifer.

The majority of the water supply wells in the Study Area are screened in the Glaciofluvial or Deltaic Package Aquifers.

Three potential aquifers have also been delineated in the Watson Lake area:

1. The Potential Deep Sands and Gravel Aquifer is a confined sand and gravel deposit identified in the YOWN-2209 S/D stratigraphic borehole which has been identified as a potential aquifer, but needs to be confirmed in future investigations.
2. The Potential Deep Glacial Outwash Sands and Gravel Aquifer is a confined sand and gravel aquifer southwest of Watson Lake and is inferred to extend to the edge of the Liard Valley.
3. The Potential Glaciofluvial Aquifer (Liard River Valley) is inferred to be the same age and depositional environment as the proven Glaciofluvial Aquifer.

The degree of saturation encountered in the environmental boreholes and lack of water supply wells are insufficient to map the Potential Deep Sand and Gravel Aquifer, the Potential Deep Glacial Outwash Sands and Gravel Aquifer and the Potential Glaciofluvial Aquifer (Liard River Valley) as proven aquifers at this time. Additional investigation with deeper wells and estimated yields would be needed to confirm the viability of the Potential Deep Sand and Gravel Aquifer, Potential Deep Glacial Outwash Sands and Gravel Aquifer units and the Potential Glaciofluvial Aquifer (Liard River Valley) as proven aquifers.

Recommendations for continuing study include:

- Digitization of YWWR well records into a database format would facilitate future mapping efforts or modifications as additional data become available.
- Survey of newly installed YOWN-2208 and YOWN-2209 S/D monitoring wells to establish a groundwater hydraulic head and a groundwater monitoring program at those wells.
- While high resolution LiDAR significantly reduces vertical uncertainty in comparison to the Canadian Digital Elevation Model (CDEM), further reduction in spatial uncertainty and errors associated with the well records could be accomplished with a well survey. Well survey data of important stratigraphic wells would increase the accuracy in the

horizontal (XY) dimension as well as the vertical (Z) dimension, providing additional confidence and stratigraphic control on the interpretation.

- Areas with limited subsurface information are candidate locations where surficial geophysical methods (electric resistivity imaging, electromagnetic methods, or seismic surveys) could be employed to better understand stratigraphy. Ideally, to interpret the geophysical data, the data should be calibrated to the stratigraphy logged from a test borehole or at the very least a competent water well log.
- Uncertainties with respect to items such as lateral extents of aquifer borders, spatial uncertainty and interconnectivity of permeable units are highlighted both in this report and in the aquifer classification worksheets. Subsurface data continues to be generated and can address gaps in the current conceptual understanding. Consideration should be given to mechanisms whereby the newly generated data that has the potential to improve the current interpretation of the subsurface is integrated and disseminated to the public in a timely manner.
- Assumptions concerning the extrapolation of aquifer boundaries using geological rationale to areas where there is limited to no subsurface lithological data are outlined on the aquifer description sheets. The implications of these assumptions should be considered within the context of the Territorial aquifer mapping and water allocation strategies. For example, is it more desirable to have a situation where an aquifer is intersected where no aquifer is mapped as a result of conservative delineation or to have a situation where an aquifer is not intersected in an area where it is anticipated to be as a result of hydrostratigraphic extrapolation?
- Additional deep boreholes or wells located away from the YOWN-2209 S/D stratigraphic borehole would be useful to confirm the bedrock topography and the presence and lateral continuity of the Potential Deep Sands and Gravel Aquifer.
- Additional deep boreholes or wells located to confirm the presence and lateral continuity of the Potential Glaciofluvial Aquifer and Potential Deep Glacial Outwash Sands and Gravel Aquifer, as well as to reduce uncertainty in the hydrostratigraphic interpretation.

References

AECOM. 2012. 2012 Town of Watson Laske Well 4 Construction and Hydrogeological Testing. Report-60241577.

Berardinucci, J. and Ronneseth, K., 2002. Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. BC Ministry of Water, Land and Air Protection, Water Air and Climate Change Branch, Water Protection Section.

EBA, 2006. Hydrogeological Assessment for Water Supply, Town of Watson Lake Well Field, Watson Lake, Yukon. EBA Engineering Consultants Ltd. 1260007.001

EBA. 2006. Building 4993 and 4944: Watson Lake EMR Fire Control Centre and Tanker Base. File 1260002.002 p. 159 -166.

EBA. 2006. Building M0092: Watson Lake RCMP Detachment. File 1260002.002 p. 76.

EBA. 2006. Building 4821: Watson Lake Weigh Scales. File 1260002.002 p. 87.

EBA. 2006. Building 4841: Watson Lake Visitor Reception Centre. File 1260002.002 p. 102.

EBA. 2006. Building 4976: Watson Lake Ambulance Building. File 1260002.002 p. 143.

Ferbey, T., Arnold, H. and Hicken, A.S., 2013. Ice-flow indicator compilation, British Columbia. British Columbia Geological Survey, Open File 2013-06.

Golder. 2013. Hydrogeology Assessment Report – Watson Lake Solid Waste Disposal Facility.

GWELLS, 2021. Groundwater Wells and Aquifer – Well Search. https://apps.nrs.gov.bc.ca/gwells/ [accessed April 1, 2021]

Morrison Hershfield. 2015. Watson Lake Well 5 Construction and Testing Report. Report No. 5150339.

Mortensen, J.K. and Murphy, D.C. (compilers), 2005. Bedrock geological map of part of Watson Lake area (all or part of NTS 105A/2, 3, 5, 6, 7, 10, 11, 12, 13, 14), southeastern Yukon (1:150 000 scale). Yukon Geological Survey, Open File 2005-10

Lipovsky, P.S. and McKenna, K., 2005. Digital compilation of local-scale biophysical mapping for integrated resource management, Watson Lake area (NTS 105A/2), Yukon. Yukon Geological Survey, Open File 2005-6.

Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial Geology Map of Watson LakeSurficial geology of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Open File 2005-7.

Tetra Tech. 2017. Source Water Protection Water Supply Protection Study. March 31, 2017. File: WTR. GWTR03022-04.

Yukon Geological Survey, 2022. Yukon digital bedrock geology. Yukon Geological Survey, http://data.geology.gov.yk.ca/Compilation/3 [accessed April 10, 2021].

Wei, M., D. M. Allen, A. P. Kohut, S. Grasby, K. Ronneseth, and B. Turner. 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater. Streamline Watershed Management Bulletin, FORREX Forum for Research and Extension in Natural Resources.

Witter, J.B, 2022. Analysis of geoscience data for geothermal exploration along the Tintina fault near Watson Lake, Yukon. Yukon Geological Survey, Open File 2022-8, 50 p. plus digital appendices. https://data.geology.gov.yk.ca/Reference/95965#InfoTab

Appendices

Appendix 1. Aquifer Description Sheets

Aquifer Description for Fan Aquifer

1. Conceptual Understanding of Hydrostratigraphy

Aquifer Extents

The Fan Aquifer is an unconfined sand and gravel aquifer located along the northern edge of Watson Lake in the vicinity of the airport. The aquifer is located at the base of fluvial / glaciofluvial channels the drain into Watson Lake. The aquifer extent is generally based on the geomorphology of the fan deposit and the distribution of the glaciofluvial deposits on the northwestern portion of Watson Lake as delineated in Quaternary mapping by Lipovsky et al. (2005).

Geologic Formation (Overlying Materials)

The aquifer is generally unconfined and exposed at surface. Some areas have been overlain by lower permeability anthropogenic materials and some areas organic material near the mouth of a small creek overly the permeable sand and gravel deposits.

Geologic Formation (Aquifer)

The aquifer consists of glaciofluvial sands and gravels and Holocene aged fluvial sands and gravels.

Vulnerability

High – the aquifer is unconfined, at surface, and likely hydraulically connected to Watson Lake and overlying creeks. The water levels observed in wells screen in this aquifer are shallow (< 10 m below surface) and the groundwater levels are typically located slightly below the water level observed in Watson Lake.

2. Conceptual Understanding of Flow Dynamics

Groundwater Levels and Flow Direction

The depth to water is shallow (< 10 m below surface), ranging from 1.6 m to 10.2 mbgs with a geometric mean of 5.0 m.

Recharge

Recharge occurs from precipitation and via infiltration from overlying creeks and from Watson Lake.

Potential for Hydraulic Connection

The aquifer is likely hydraulically connected to Watson Lake and overlying creeks that drain towards Watson Lake.

3. Water Management

Additional Information on Water Use and Management

A limited number of the wells (< 10 wells) in the Watson Lake area are inferred to be screened in the Fan aquifer, primarily consisting of small water supply for activities associated with the Airport. Well yields, estimated at time of development, range from 19 to 570 L/min (5 to 150 GPM) with a geomean of 93 L/min (25 USGPM).

Water quality testing at the Airport Pumphouse well identified total iron concentrations between 1.28 mg/L and 3.14 mg/L which exceeds Government of Canada Drinking Water Quality aesthetic objective (GCDWQ AO) of 0.3 mg/L (Tetra Tech, 2017). Total manganese was measured between 1.84 to 2.69 mg/L and dissolved manganese was measured at 2.65 mg/L which also exceeds the GCDWQ AO. At the time of testing, hydrocarbons (EPH and PAHs) were below the detection limit of the lab.

Additional Assessments or Management Actions

A water supply assessment of a number of wells in the Watson Lake area was completed by EBA in 2006 which included the Watson Lake EMR Fire Control centre and Tanker Base well located in the Fan Aquifer. Additional environmental wells at the north of the Airport were installed by Franz Environmental Inc. as part of the Watson Lake hydrogeology Study (2010).

Tetra Tech recommended a Source Water Protection Plan be developed for the Watson Lake Airport water supply system given the proximity to the sewer lines and reported hydrocarbon contamination in soils in close proximity to the well.

4. Aquifer references

Berardinucci, J. and Ronneseth, K., 2002. Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. BC Ministry of Water, Land and Air Protection, Water Air and Climate Change Branch, Water Protection Section.

EBA, 2006. Hydrogeological Assessment for Water Supply, Town of Watson Lake Well Field, Watson Lake, Yukon. EBA Engineering Consultants Ltd. 1260007.001

EBA. 2006. Building 4993 and 4944: Watson Lake EMR Fire Control Centre and Tanker Base. File 1260002.002 p. 159 -166.

Surficial Geology Map of Watson Lake(Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial geology of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Open File 2005-7.)

Tetra Tech. 2017. Source Water Protection Water Supply Protection Study. March 31, 2017. File: WTR. GWTR03022-04.

Wei, M., D. M. Allen, A. P. Kohut, S. Grasby, K. Ronneseth, and B. Turner. 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater. Streamline Watershed Management Bulletin, FORREX Forum for Research and Extension in Natural Resources.

5. Revision history

Date	Version	Revision Class	Comments	Author
20221122	001	Major	Initial mapping of aquifer	WSP

Aquifer Description for Glaciofluvial Aquifer

1. **Conceptual Understanding of Hydrostratigraphy**

Aquifer Extents

The Glaciofluvial Aquifer is an unconfined sand and gravel aquifer located throughout the bedrock valley south-east of Watson Lake. The aquifer extent is generally constrained to the distribution of the glaciofluvial deposits on the eastern portion of Watson Lake as delineated in Quaternary mapping by Lipovsky, P.S., et al. (2005).

Geologic Formation (Overlying Materials)

The aquifer is unconfined with some areas of overlying organic material.

Geologic Formation (Aquifer)

The aquifer consists medium to coarse sand and gravel with some silt. The aquifer is inferred to be associated with glacial outwash during the glacial retreat to the south of the Study Area. The YOWN-2209 S/D stratigraphic borehole completed by the YG WRB suggests that the unit is up to 15 m thick and is described as a medium gravelly sand.

Vulnerability

High – the aquifer is unconfined, and the water table is typically shallow (< 10 m below surface). The aquifer is likely hydraulically connected to Watson Lake along the western edge of the aquifer and directly to the various small kettle lakes in the Study Area. Some areas of the overlying finer-grained material may be present that may provide a degree of confinement in some locations but these are expected to be variable and discontinuous.

1. **Conceptual Understanding of Flow Dynamics**

Groundwater levels and flow direction

Groundwater levels for wells inferred to be screened in the aquifer unit are between 4 m and 14 m below ground with an average depth of 7.5 mbgs. The depth to water is generally shallower than wells inferred to be screened in the Deltaic Package Aquifer. Regional groundwater flow directions are expected to be towards regional drainage and Watson Lake.

Recharge

Recharge occurs direct precipitation and regional groundwater flow from the valley.

Potential for hydraulic connection

The aquifer is assumed to be hydraulically connected to Watson Lake and indirectly to the kettle lakes in the Study Area.

2. **Water Management**

Additional information on water use and management

Wells screened in Glaciofluvial Aquifer are used for private domestic purposes, water supply purposes, and environmental monitoring. Well yield estimates for this aquifer obtained from airlifting during development range from 8 to 850 L/min (2 to 225 USGPM) with a geomean of 80 L/min (21 USGPM). A number of small supply wells and domestic wells are inferred to be screened in this aquifer based on wells depths, however detailed lithological well logs were not available for a number of these wells.

Additional Assessments or Management Actions

Not available

3. Aquifer references

Berardinucci, J. and Ronneseth, K., 2002. Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. BC Ministry of Water, Land and Air Protection, Water Air and Climate Change Branch, Water Protection Section.

EBA, 2006. Hydrogeological Assessment for Water Supply, Town of Watson Lake Well Field, Watson Lake, Yukon. EBA Engineering Consultants Ltd. 1260007.001

EBA. 2006. Building M0092: Watson Lake RCMP Detachment. File 1260002.002 p. 76.

EBA. 2006. Building 4821: Watson Lake Weigh Scales. File 1260002.002 p. 87.

EBA. 2006. Building 4841: Watson Lake Visitor Reception Centre. File 1260002.002 p. 102.

EBA. 2006. Building 4976: Watson Lake Ambulance Building. File 1260002.002 p. 143.

Surficial Geology Map of Watson Lake(Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial geology of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Open File 2005-7.)

Tetra Tech. 2017. Source Water Protection Water Supply Protection Study. March 31, 2017. File: WTR. GWTR03022-04.

Wei, M., D. M. Allen, A. P. Kohut, S. Grasby, K. Ronneseth, and B. Turner. 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater. Streamline Watershed Management Bulletin, FORREX Forum for Research and Extension in Natural Resources.

4. Revision history

Date	Version	Revision Class	Comments	Author
20221122	001	Major	Initial mapping of aquifer	WSP

Aquifer Description for Deltaic Package Aquifer

1. Conceptual Understanding of Hydrostratigraphy

Aquifer Extents

The Deltaic Package Aquifer is an unconfined sand and gravel aquifer comprised of thick sand package located throughout the bedrock valley south of Watson Lake. The aquifer underlies the surficial glaciofluvial deposits that are exposed at surface throughout the valley. The deposit is expected to be laterally extensive across the bedrock valley underlying the Town of Watson Lake and likely extends further east of the Study Area.

Geologic Formation (Overlying Materials)

The aquifer is overlain by the glaciofluvial sand and gravels associated with glaciofluvial deposits mapped at surface in the valley. Local areas of finer silt and minor clay units have been noted near the interface of the deltaic package and glaciofluvial deposits, however these finer deposits are expected to be variable in composition and thickness, and discontinuous throughout the Study Area.

Geologic Formation (Aquifer)

The aquifer consists of a thick sequence of fine to medium sand transitioning medium sand and gravel with some wood fragments. The aquifer is likely associated with a glacial deltaic environment as the area underwent a transition from a glacial lake to extensive glacial outwash plains during the glacial retreat the to south. The YOWN-2209 S/D stratigraphic borehole completed by the YG WRB suggests that the unit in the valley is thick and generally coarsens from the bottom upwards in the eastern portion of the unit. Heaving sands encountered during drilling resulted in large sections of core through this deposit being lost, however, the sequence is roughly 25 m thick at this location.

Vulnerability

High – the aquifer is unconfined to partially confined, and the water table is typically shallow (< 10 m below surface). The aquifer is hydraulically connected to the overlying Glaciofluvial Aquifer, Watson Lake along the western edge of the aquifer and likely in directly to the various small kettle lakes in the Study area. Some areas of the overlying finer-grained silts to silty/clay deposits are present overlying the aquifer. These lower permeability sediments are variable and discontinuous but may provide some degree of confinement in some locations.

2. Conceptual Understanding of Flow Dynamics

Groundwater levels and flow direction

Groundwater wells are relatively limited in the area, however the groundwater levels for wells inferred to be screened in the aquifer unit are between 2 m and 16 m below ground with an average depth of 9 mbgs. Regional groundwater is expected to flow from higher elevations to lower elevations, roughly approximating the regional drainage.

Recharge

Recharge occurs from infiltration from the overlying Glaciofluvial Aquifer, Watson Lake and indirectly via precipitation from the highlands.

Potential for hydraulic connection

The aquifer is assumed to be hydraulically connected to the overlying Glaciofluvial Aquifer, likely Watson Lake and indirectly to the kettle lakes in the Study Area.

3. Water Management

Additional information on water use and management

Wells screened in Deltaic Package Aquifer are used for private domestic purposes, water supply purposes, and environmental monitoring. Well yield estimates for this aquifer range from 8 to 1800 L/min (5 to 475 USGPM) with a geomean of 102 L/min (27 USGPM).

Based on the lithology logs, large water supply wells Well 1A, Well 2, Well 3, Well 4 are inferred to be screened in the Deltaic Package Aquifer (EBA 2006). In the Source Water Protection Plan for Wells 4 and 5 (Tetra Tech, 2017), these wells were inferred to be screened in the unconfined glaciofluvial sediments of the Glaciofluvial Aquifer. However, based on the depths of the intersected Deltaic Package Aquifer at newly drilled YOWN-2209 S/D and a wider interpretation of other local well records in the area these wells are now inferred to be screened in the deep Deltaic Package Aquifer although there is likely a hydraulic connection to the overlying Glaciofluvial Aquifer. These wells were identified as Non-GUDI (Groundwater Under Direct Influence of Surface Water), however, these wells are part of the public water supply system, and thus pre-chlorination, green sand filtration and secondary chloring disinfection are used as treatment (Tetra Tech, 2017).

Additional Assessments or Management Actions

A Source Water Protection Plan for the Town of Watson Lake municipal water supply wells was completed in by Tetra Tech in 2017. Water supplied by Well 4 and Well 5 was considered hard with hardness of 156 mg/L and 209 mg/L, respectively. Iron and manganese concentrations exceeded the GCDWQG AO. Similarly, in the Source Water Protection Plan for the LFN 2 Mile Community wells TW05-02 and TW05-03, water was classified at calcium-bicarbonate type with hardness measured at 167 mg/L and 214 mg/L respectively (Tetra Tech, 2017). Iron concentrations exceeded the GCDWQ AO of 0.3 mg/L and were found to be as 2 mg/L in January 2006. Manganese also exceeded the GCDWQG AO of 0.05 mg/L.

4. Aquifer references

AECOM. 2012. 2012 Town of Watson Laske Well 4 Construction and Hydrogeological Testing. Report-60241577.

Berardinucci, J. and Ronneseth, K., 2002. Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater. BC Ministry of Water, Land and Air Protection, Water Air and Climate Change Branch, Water Protection Section.

EBA, 2006. Hydrogeological Assessment for Water Supply, Town of Watson Lake Well Field, Watson Lake, Yukon. EBA Engineering Consultants Ltd. 1260007.001

Morrison Hershfield. 2015. Watson Lake Well 5 Construction and Testing Report. Report No. 5150339.

Surficial Geology Map of Watson Lake(Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial geology of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Open File 2005-7.)

Tetra Tech. 2017. Source Water Protection Water Supply Protection Study. March 31, 2017. File: WTR. GWTR03022-04.

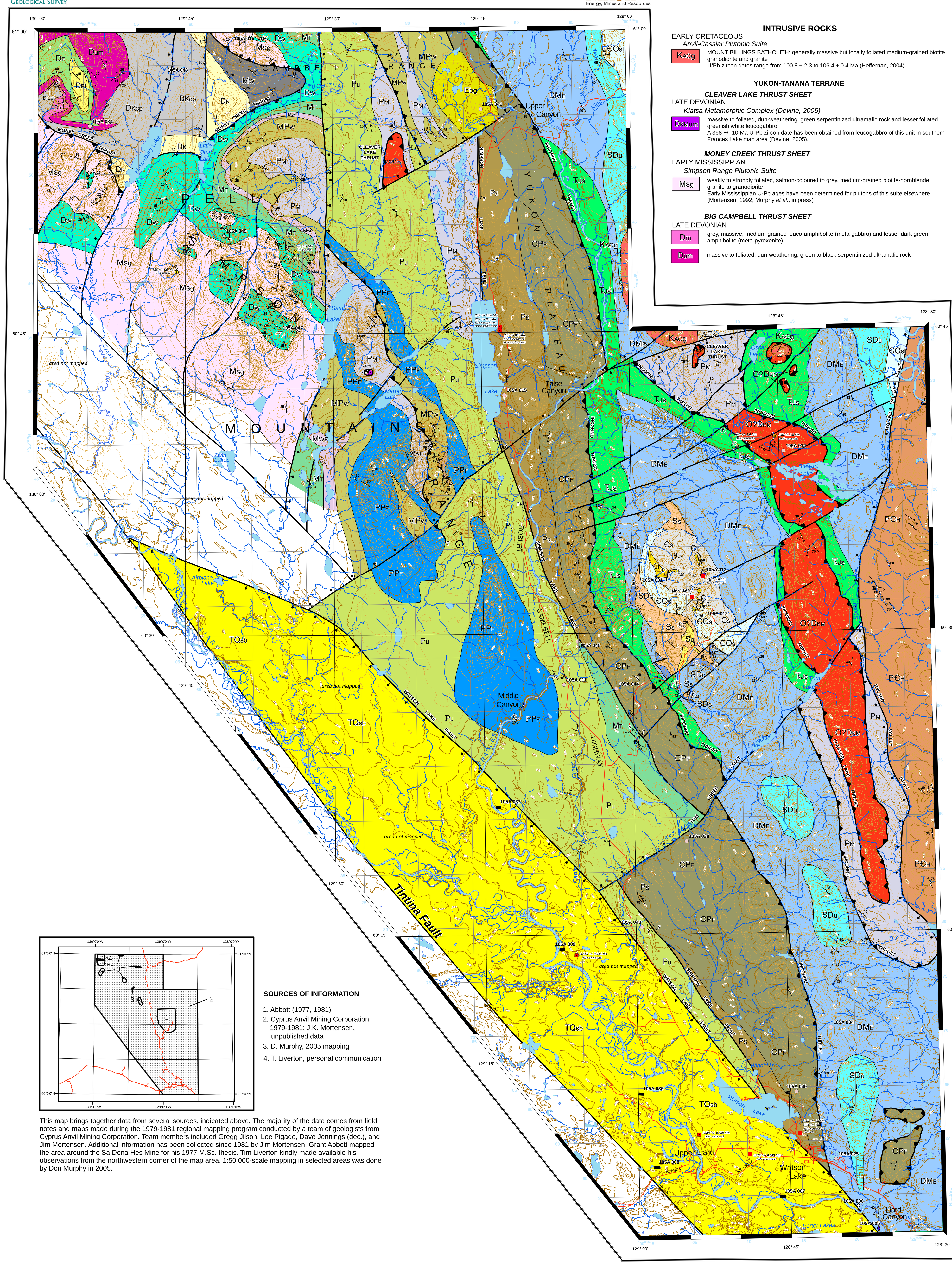
Wei, M., D. M. Allen, A. P. Kohut, S. Grasby, K. Ronneseth, and B. Turner. 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeologic Region to Better Manage and Protect Groundwater. Streamline Watershed Management Bulletin, FORREX Forum for Research and Extension in Natural Resources.

5. Revision history

Date	Version	Revision Class	Comments	Author
20221122	001	Major	Initial mapping of aquifer	WSP

Appendix 2. Geological Mapping

Yukon Geological Survey
Yukon Energy, Mines and Resources



LEGEND

INTRUSIVE ROCKS

EARLY CRETACEOUS
Anvil-Cassiar Plutonic Suite

KACg MOUNT BILLINGS BATHOLITH: generally massive but locally foliated medium-grained biotite granodiorite and granite
U/Pb zircon dates range from 100.8 ± 2.3 to 106.4 ± 0.4 Ma (Heffernan, 2004).

YUKON-TANANA TERRANE

CLEAVER LAKE THRUST SHEET

LATE DEVONIAN
Klatsa Metamorphic Complex (Devine, 2005)

DKMum massive to foliated, dun-weathering, green serpentinized ultramafic rock and lesser foliated greenish white leucogabbro
A 368 +/- 10 Ma U-Pb zircon date has been obtained from leucogabbro of this unit in southern Frances Lake map area (Devine, 2005).

MONEY CREEK THRUST SHEET

EARLY MISSISSIPPIAN
Simpson Range Plutonic Suite

Msg weakly to strongly foliated, salmon-coloured to grey, medium-grained biotite-hornblende granite to granodiorite
Early Mississippian U-Pb ages have been determined for plutons of this suite elsewhere (Mortensen, 1992; Murphy *et al.*, in press)

BIG CAMPBELL THRUST SHEET

LATE DEVONIAN

Dm grey, massive, medium-grained leuco-amphibolite (meta-gabbro) and lesser dark green amphibolite (meta-pyroxenite)

Dum massive to foliated, dun-weathering, green to black serpentinized ultramafic rock

LAYERED ROCKS

CENOZOIC

TQsb undifferentiated Holocene basalt and Eocene sedimentary rocks

EOCENE

Ebg brown-weathering, greenish black basalt, locally associated with gabbro (not differentiated)

YUKON-TANANA TERRANE

CLEAVER LAKE THRUST SHEET

UPPER ORDOVICIAN?, SILURIAN(?) OR DEVONIAN(?)
Klatsa Metamorphic Complex (Devine, 2005)

O?DKM coarse-grained metamorphic rocks contained as blocks within serpentinized ultramafic rocks (unit DKMum)
Rock types include variably carbonaceous quartz-muscovite schist and garnet and omphacite-bearing metabasite. Detrital zircons extracted from metaclastic rocks are as young as Early Ordovician; U-Pb dating on metamorphic zircon and Ar-Ar dating on retrograde muscovite indicate that prograde metamorphism and uplift occurred at ca. 354 Ma (Devine, 2005).

MONEY CREEK THRUST SHEET

LOWER PERMIAN
Money Creek Formation

PM undifferentiated medium to dark grey carbonaceous phyllite; grey and lesser green and pink chert; grey quartzite and mottled grey-white chert-pebble conglomerate, chert-quartz wacke and grit

PENNSYLVANIAN-LOWER PERMIAN
Finlayson Creek Limestone

PPF massive to thickly bedded, light to medium grey, light grey-weathering, locally crinoidal limestone
Pennsylvanian to Early Permian conodonts have been extracted from this unit elsewhere (Murphy *et al., in press*; Orchard, *in press*).

UPPER MISSISSIPPIAN-PENNSYLVANIAN

Pu undifferentiated King Arctic and White Lake formations

PENNSYLVANIAN
King Arctic Formation (Devine, 2005)

PKA undifferentiated green to pale grey, fine- to medium-grained lithic arenite, quartz wacke and chert-pebble conglomerate; dark grey argillite; chloritic phyllite (mafic to intermediate meta-volcanic rocks)

UPPER MISSISSIPPIAN-LOWER PENNSYLVANIAN
White Lake Formation (Devine, 2005)

MPW undifferentiated green and locally pink, locally magnetite-bearing chert; fine-grained lithic wacke and siltstone; and white to grey locally sandy and crinoidal limestone
Greenstone, dark phyllite and limestone and chert-pebble conglomerate occur locally.
Conodonts of Serpukhovian age have been extracted from this unit elsewhere (Murphy *et al., in press*; Orchard, *in press*).

UPPER MISSISSIPPIAN
Whitefish Limestone

MWF massive to thickly bedded, light to medium grey, light grey-weathering, locally crinoidal limestone
Conodonts of Serpukhovian age have been extracted from this unit elsewhere (Murphy *et al., in press*; Orchard, *in press*).

LOWER MISSISSIPPIAN
Tuchitua River Formation

MT variably foliated and massive, pale green, tan and maroon crystal-lithic tuff breccia; massive pistacchio-green quartz- and feldspar-phyric meta-rhyolite; local accumulations of green chert- and phyllite-clast conglomerate and grit near base
Early Mississippian U-Pb ages have been determined for this unit elsewhere (Mortensen, 1992; Murphy *et al., in press*).

UPPER DEVONIAN
Waters Creek Formation

DW siliceous muscovite-quartz schist or phyllite (felsic metavolcanic rock) and lesser chloritic schist or phyllite (intermediate to mafic metavolcanic rock) intercalated with carbonaceous phyllite; massive to ribbon-bedded, green, white and salmon siliceous rock (meta-chert?) at top
A member of quartzite and quartz-pebble meta-conglomerate occurs near the middle of the succession.

BIG CAMPBELL THRUST SHEET

LOWER MISSISSIPPIAN
Wolverine Lake Group

MW quartzofeldspathic grit and pebble meta-conglomerate; lesser carbonaceous phyllite; rare meta-rhyolite, locally amygdaloidal
Early Mississippian U-Pb dates have been obtained from this unit elsewhere (Mortensen, 1992; Murphy *et al., in press*).

UPPER DEVONIAN
Kudz Ze Kayah Formation

DK undifferentiated foliated feldspar-muscovite-quartz schist or phyllite, massive pale siliceous muscovite-quartz schist or phyllite, locally with quartz amygdules; feldspar- and rarely quartz-augen schist or phyllite (meta-porphyry). Interbeds of carbonaceous phyllite are common

DKcp carbonaceous phyllite and grey quartzite

Fire Lake Formation

DF massive to subtly layered, plagioclase-chlorite phyllite or schist, locally with biotite and actinolite porphyroblasts; lesser carbonaceous phyllite

DFf tan muscovite-quartz phyllite or schist (felsic metavolcanic rock) and potassium feldspar-muscovite-quartz augen phyllite or schist (meta-porphyry); locally rusty and pyritic

SLIDE MOUNTAIN TERRANE

UPPER MIDDLE-UPPER PERMIAN
Simpson Lake Group

PS red-brown to pale green matrix- and framework-supported polymictic conglomerate, pale green sandstone, dark grey siltstone and shale, basalt and felsic volcanic rocks
Conglomerate clasts include porphyritic basalt, aphyric massive basalt, chloritic phyllite, quartz-mica phyllite, siliceous carbonaceous phyllite, carbonate, white quartz, chert, serpentinite, blueschist and eclogite (Mortensen et al., 1999; Murphy et al., in press). Middle to Late Permian U-Pb zircon ages have been determined for felsic volcanic rocks of this unit (Mortensen et al., 1999).

CARBONIFEROUS (AND OLDER?)-PERMIAN
Fortin Creek Group

CPF variably foliated, matte green and grey, ribbon-bedded to massive chert; medium to dark grey and lesser green and pink shale or phyllite; quartzofeldspathic sandstone, grit and conglomerate and chert-quartz sandstone, grit and conglomerate

NORTH AMERICAN CONTINENTAL MARGIN SEQUENCE

MIDDLE-UPPER TRIASSIC
Jones Lake Formation (Gordey and Anderson, 1993)

TrJs dark brown- and grey-weathering, greenish-brown to grey, detrital mica-bearing calcareous shale, siltstone, sandstone and silty limestone

UPPER DEVONIAN-LOWER MISSISSIPPIAN
Earn Group

DME dark grey- black- and rusty-weathering non-calcareous shale, siltstone, quartz and chert wacke, and minor chert-pebble conglomerate (Abbott, 1977, 1981)

SILURIAN-DEVONIAN

SDu undifferentiated dolomite, dolomitic siltstone, dolomitic quartzite and orthoquartzite

UPPER SILURIAN(?)-LOWER DEVONIAN

SDc dark grey, fetid, platy limestone; thick-bedded, buff-weathering sandy dolomite; dolomitic quartzite (Abbott, 1977, 1981)
Unit may be in part equivalent to McDame Formation of Gabrielse (1998).

SILURIAN

Ss thinly laminated, brown, grey- and buff-weathering calcareous or dolomitic siltstone, silty dolomite, dolomite (Abbott, 1977, 1981)
May be in part equivalent to Sandpile Formation of Gabrielse (1998).

Sq massive, resistant, blue-grey orthoquartzite occurring as lenses within dolomitic siltstone of unit near its base (Abbott, 1977, 1981)
Unit may be lateral facies equivalent of the Ramhorn Formation of Gabrielse (1998).

UPPER CAMBRIAN-LOWER ORDOVICIAN

COsl undifferentiated thinly laminated or nodular, calcareous grey and brown phyllite and silty limestone; thinly laminated green and purple calc-silicate hornfels (Abbott, 1977, 1981)
Unit is transitional lithologically between time-equivalent Rabbitkettle and Kechika formations of Selwyn Basin and Cassiar Platform, respectively (J.G. Abbott, personal communication, 2005).

LOWER CAMBRIAN

Cl massive blue-grey, *Archeocyathid*-bearing limestone occurring as lenses within unit Cs (Abbott, 1977, 1981)

Cs silver, greenish-grey phyllite, brown and grey micaceous and/or calcareous phyllite, black quartzose phyllite, minor greenstone (Abbott, 1977, 1981)

UPPER PROTEROZOIC-LOWER CAMBRIAN
Hyland Group

PCH undiffentiated quartzofeldspathic grit and sandstone, slate, massive siliceous limestone, maroon and green slate

MINERAL OCCURRENCES
Yukon MINFILE (Deklerk and Traynor, 2005)

MINFILE #	NAME	STATUS	COMMODITY	DEPOSIT TYPE
105A 004	Windfall	unknown		unknown
105A 005	Watson	drilled prospect	Zn, Pb, Ag	vein
105A 006	Nazo	drilled prospect	Ag, Pb, Zn	vein
105A 007	Carol	drilled prospect	coal	coal
105A 008	Albert	drilled prospect	coal	coal
105A 009	Sawmill	showing	coal	coal
105A 011	Carnegie	anomaly		unknown
105A 012	Sa Dena Hes, Mt. Hundere	underground past producer	Ag, Zn, Pb	skarn
105A 013	Ritco, North HIll, Mt. Hundere, Sa Dena Hes	underground past producer	Pb, Ag, Zn	skarn
105A 014	Ralph	unknown		unknown
105A 015	Simpson, Simpson Lake	unknown		unknown
105A 016	Heisz	unknown		unknown
105A 025	Mymryk	unknown		unknown
105A 031	Plan	unknown		unknown
105A 034	Howard	unknown		unknown
105A 036	Dodo	prospect	coal	coal
105A 037	Middle Canyon	showing	coal	coal
105A 038	Shell	anomaly		unknown
105A 040	Skihill	unknown		unknown
105A 041	Pug	unknown		unknown
105A 043	Glimmer	anomaly		unknown
105A 044	Highway	anomaly		unknown
105A 045	Jewel	unknown		unknown
105A 047	Sambo, Simpson	prospect	Ag, Pb, Cu, Zn	Kuroko massive sulphide
105A 048	Itch	anomaly		unknown
105A 049	Little Jimmy	showing		volcanogenic massive sulphide

SYMBOLS

geological contact (approximate)
fault; movement not known (approximate)
thrust fault (approximate)
dextral strike-slip fault (approximate, queried where displacement direction uncertain)
normal fault (approximate)
bedding
bedding, upright
compositional layering
foliation, early
foliation, dominant
foliation, late
radiometric date (U/Pb, Ar/Ar, K/Ar; from Breitsprecher *et al.*, 2003) — 351 ± 1 Ma U/Pb zircon; 361 Ma K/Ar whole rock; 191 ± 1 Ma Ar/Ar muscovite
Yukon MINFILE occurrence (tabulated below) — 105A 023
fossil locality (numbers refer to records tabulated below)
field station — Murphy, 2005; Cyprus Anvil, 1979-1981
road

FOSSILS

Map Number	GSC Number	Material	Map Unit	Age Range	Reference
1	C-068289	pollen	TQsb	Late Eocene	Poulton *et al.* (2003)
2	O-087031	conodonts	TrJs	Middle Triassic (Ladinian)	Orchard (in press)
3	O-087032	conodonts	TrJs	Middle Triassic (Anisian-Ladinian)	Orchard (in press)
4	O-075640	conodonts	TrJs?	Ordovician-Silurian	Poulton *et al.* (2003)
5	O-086368	conodonts	TrJs?	Late Devonian	M.J. Orchard (unpub.)
6	C-303414	conodonts	Ps	Permian	Orchard (in press)
7	C-303415	conodonts	Ps	probably Permian	Orchard (in press)
8	C-102798	conodonts	PPF	Late Carboniferous (Bashkirian)	Orchard (in press)
9	C-026571	conodonts	DME	probably Devonian	Poulton *et al.* (2003)
10	O-086357	conodonts	DME	Middle to Late Devonian	M.J. Orchard (unpub.)
11	C-026569	conodonts	SDc	Early Devonian	Poulton *et al.* (2003)
12	C-026570	conodonts	SDc	Early to Middle Devonian	Poulton *et al.* (2003)
13	C-116326	conodonts	SDc	Early-early Middle Devonian (late Emsian-early Eifelian)	M.J. Orchard (unpub.)
14	C-026576	graptolites	Ss	Silurian, probably latest (Llandovery or Wenlock)	Abbott (1977)
15	C-026579	graptolites	Ss	Ordovician-Early Devonian	Abbott (1977)
16	C-026578	archeocyathids	Cl	Early Cambrian	Abbott (1977)
17	C-026572	archeocyathids	Cl	Early Cambrian	Abbott (1977)
18	C-026573	archeocyathids	Cl	Early Cambrian	Abbott (1977)
19	C-026574	archeocyathids	Cl	Early Cambrian	Abbott (1977)
20	C-026575	archeocyathids	Cl	Early Cambrian	Abbott (1977)
21	O-089874	archeocyathids	Cl	Early Cambrian	Poulton *et al.* (2003)

REFERENCES

Abbott, J.G., 1977. Structure and stratigraphy of the Mt. Hundere area, southeastern Yukon. Unpublished M.A. Sc. thesis. Queens University, Kingston, Ontario, 111 p.

Abbott, J.G., 1981. A new geological map of the Mt. Hundere and the area north. *In:* Yukon Exploration 1979-1980, Exploration and Geological Services Division, Yukon Region, Indian and Northern Affairs, Canadap. 45-50.

Breitsprecher, K. , Mortensen, J.K. and Villeneuve, M.E. (comp.), 2003. YukonAge 2002-A database of isotopic age determinations for rock units from Yukon Territory *In:* Yukon digital geology, version 2.0, S.P. Gordey and A.J. Makepeace (comp.), Geological Survey of Canada, Open File 1749 and Yukon Geological Survey, Open File 2003-9(D)

Deklerk, R. and Traynor, S. (comp), 2005. Yukon MINFILE 2005 - A database of mineral occurrences. Yukon Geological Survey, 2 CD-ROMs.

Devine, F., 2005. Geology of the southern Campbell Range, southeastern Yukon: implications for the evolution of Yukon-Tanana Terrane. Unpublished M.Sc. thesis. Carleton University, Ottawa, Ontario,133 p.

Devine, F.D., Carr, S.D., Murphy, D.C., Davis, W.J., Smith, S., and Villeneuve, M., *in press.* Geochronological and geochemical constraints on the origin of the Klatsa metamorphic complex: implications for Early Mississippian high-pressure metamorphism within Yukon-Tanana terrane. *In:* Paleozoic evolution and metallogeny of pericratonic terranes at the ancient Pacific margin of North America, Canadian and Alaskan Cordillera, M. Colpron, J.L. Nelson, and R.I. Thompson, *(eds.)*, Geological Association of Canada, Special Paper.

Gabrielse, H. 1998. Geology of Cry Lake and Dease Lake map areas, north-central British Columbia. Geological Survey of Canada, Bulletin 504, 147 p.

Gordey, S.P. and Anderson, R.G., 1993. Evolution of the northern Cordilleran miogeocline, Nahanni map area (105I), Yukon and Northwest Territories. Geological Survey of Canada, Memoir 428, 214 p.

Heffernan, R.S., 2004. Temporal, geochemical, isotopic, and metallogenic studies of mid-Cretaceous magmatism in the Tintina Gold Province, southeastern Yukon and southwestern Northwest Territories, Canada. University of British Columbia, Unpublished MSc thesis, Vancouver, BC, 83 p.

Mortensen, J.K., 1992. Pre-mid-Mesozoic tectonic evolution of the Yukon-Tanana Terrane, Yukon and Alaska. Tectonics, vol. 11, p. 836-853.

Mortensen , J.K., Erdmer, P., Piercey, S.J., and Ghent, E.D., 1999. Evidence for Late Triassic terrane accretion in the northern Canadian Cordillera in southeastern Yukon [abstract]. *In:* Terrane Paths 99, C.A. Evenchick, G.J. Woodsworth, and R. Jongens, *(eds.)*, Circum-Pacific Terrane Conference Abstract Volume, Geological Survey of Canada/Geological Association of Canada, p. 55.

Murphy, D.C., Mortensen, J.K., Piercey, S.J., Orchard, M.J. and Gehrels, G., *in press*. Mid-Paleozoic to Early Mesozoic tectonostratigraphic evolution of Yukon-Tanana and Slide Mountain terranes and affiliated overlap assemblages, Finlayson Lake massive sulphide district, southeastern Yukon. *In:* Paleozoic evolution and metallogeny of pericratonic terranes at the ancient Pacific margin of North America, Canadian and Alaskan Cordillera, M. Colpron, J.L. Nelson, and R.I. Thompson, *(eds.)*, Geological Association of Canada, Special Paper.

Orchard, M.J., *in press*. Late Paleozoic and Triassic conodont faunas of Yukon Territory and northern British Columbia and implications for the evolution of Yukon-Tanana terrane, *In:* Paleozoic evolution and metallogeny of pericratonic terranes at the ancient Pacific margin of North America, Canadian and Alaskan Cordillera, M. Colpron, J.L. Nelson, and R.I. Thompson, *(eds.)*, Geological Association of Canada, Special Paper.

Poulton, T., Orchard, M.J., Gordey, S.P., and Davenport, P. (comp.), 2003. Selected Yukon fossil determinations *In:* Yukon digital geology, version 2.0, S.P. Gordey and A.J. Makepeace (comp.), Geological Survey of Canada, Open File 1749 and Yukon Geological Survey, Open File 2003-9(D).

RECOMMENDED CITATION

MORTENSEN, J.K. and MURPHY, D.C. (compilers), 2005. Bedrock geological map of part of Watson Lake area (all or part of NTS 105A/2, 3, 5, 6, 7, 10, 11, 12, 13, 14), southeastern Yukon (1:150 000 scale). Yukon Geological Survey, Open File 2005-10

Digital cartography and drafting by Donald Murphy, with the assistance of Olwyn Bruce and Amy Stuart, all of Yukon Geological Survey.

ACKNOWLEDGEMENTS

The authors would like to thank Dejan Milidragovic for assistance in the field in 2005 and starting the compilation of the Cyprus Anvil data into a digital database. We are also grateful to Amber Church for continuing the database compilation and to Andy Robertson of Trans North Helicopters for rainbow trout and safe and uneventful flying.

Any revisions or additional geological information known to the user would be welcomed by the Yukon Geological Survey.

Paper copies of this map, the accompanying report and Yukon MINFILE may be purchased from Geoscience Information and Sales, c/o Whitehorse Mining Recorder, Energy, Mines and Resources, Government of Yukon, Room 102 - 300 Main St., Whitehorse, Yukon, Y1A 2B5. Ph. 867-667-5200, Fax. 867-667-5150, Email: geosales@gov.yk.ca.

A digital PDF (Portable Document File) file of this map may be downloaded free of charge from the Yukon Geological Survey website: http://www.geology.gov.yk.ca.

Yukon Geological Survey
Energy, Mines and Resources
Government of Yukon

Open File 2005-10

Bedrock geological map of part of Watson Lake area (all or part of NTS 105A/2, 3, 5, 6, 7, 10, 11, 12, 13, 14), southeastern Yukon, (1:150 000 scale)

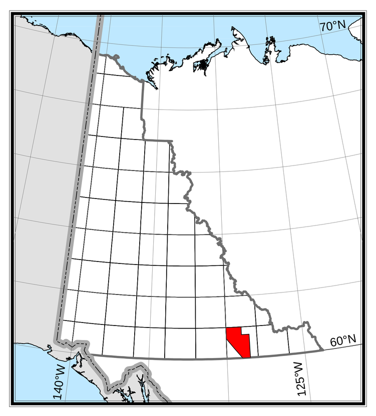
compiled by

James K. Mortensen and Donald C. Murphy

SOURCES OF INFORMATION

1. Abbott (1977, 1981)
2. Cyprus Anvil Mining Corporation, 1979-1981; J.K. Mortensen, unpublished data
3. D. Murphy, 2005 mapping
4. T. Liverton, personal communication

This map brings together data from several sources, indicated above. The majority of the data comes from field notes and maps made during the 1979-1981 regional mapping program conducted by a team of geologists from Cyprus Anvil Mining Corporation. Team members included Gregg Jilson, Lee Pigage, Dave Jennings (dec.), and Jim Mortensen. Additional information has been collected since 1981 by Jim Mortensen. Grant Abbott mapped the area around the Sa Dena Hes Mine for his 1977 M.Sc. thesis. Tim Liverton kindly made available his observations from the northwestern corner of the map area. 1:50 000-scale mapping in selected areas was done by Don Murphy in 2005.



Topographic base data from 1:50 000 scale data produced by CENTRE FOR TOPOGRAPHIC INFORMATION, NATURAL RESOURCES CANADA

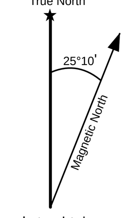
FIVE THOUSAND METRE GRID
Universal Transverse Mercator Projection
North American Datum 1983
Zone 9

CONTOUR INTERVAL 100 FEET
Elevations in feet above Mean Sea Level

BEDROCK GEOLOGY
WATSON LAKE (part)
YUKON

SCALE 1:150 000

0 5 10 15 20 25
kilometres



Use diagram only to obtain numerical values
APPROXIMATE MEAN DECLINATION 2005
FOR CENTRE OF MAP
Grid North approximates True North
throughout much of area.

105A/13 HASSELBERG LAKE	105A/14 UPPER CANYON	105A/15 MOUNT MURRAY
105A/12 SAMBO CREEK	105A/11 FALSE CANYON	105A/10 STEWART LAKE
105A/5 FALSE PASS CREEK	105A/6 MIDDLE CANYON	105A/7 TOM LAKE
105A/4 ALLEGRETTO LAKE	105A/3 DODO LAKES	105A/2 WATSON LAKE

Canada

Indian and Northern Affairs Canada
Affaires indiennes et du Nord Canada
Knowledge & Innovation Fund

Yukon Geological Survey

Yukon Energy, Mines and Resources

PROJECT BACKGROUND

This map was produced as part of a biophysical mapping pilot study carried out in the Watson Lake (NTS 105A/2) area in 2004. Biophysical mapping (also known as ecological land classification) is an integrated system of mapping describing terrain conditions (surficial geology, slope, landscape position, drainage and permafrost conditions) as well as ecological values (vegetation community and structure, and soil moisture and nutrient regimes). At a local (1:50 000) scale, biophysical maps are an essential tool for facilitating stewardship and sustainable development of energy, mineral and land resources.

This map accompanies the report "Local scale biophysical mapping for integrated resource management, Watson Lake area (NTS 105A/2), Yukon" (Lipovsky and McKenna, 2005). Please refer to this report for more detailed background, methodology and descriptions of map units; GIS data is also included with the report on CD-ROM.

GLACIAL HISTORY

The Watson Lake map area has been glaciated at least six times since the Quaternary period (the last 2 million years; Jackson et. al, 1991). Aside from scattered section localities, evidence of the older glacial episodes are completely masked by deposits from the latest glaciation, which is known as the McConnell Glaciation. During this late Wisconsinan McConnell Glaciation, the Liard Lobe of the Cordilleran ice sheet flowed in an easterly direction out of the Cassiar Mountains and in a southeasterly direction out of the Pelly and Selwyn mountains, following the Tintina Trench/Liard Lowland.

At Tom Creek, just northwest of the map area, twig fragments in a silt unit underlying the McConnell till were found to be as young as 23 900 ± 1140 BP by radiocarbon dating (Klassen, 1987), implying that the onset of glaciation in the Watson Lake area occurred some time after that. The timing of deglaciation likely occurred after 10 700 years ago, according to radiocarbon dating on Marcella Lake cores in southwestern Yukon (Anderson et al., 2002). At the height of the McConnell Glaciation, ice in the Liard Lowland would have overtopped the highest uplands suggesting a minimum ice thickness of at least 500 m.

Northeast of the Liard River floodplain, a thick, gently undulating and rolling till plain is extensively streamlined with drumlins, flutings and grooves that provide clear indications of southeasterly to easterly ice flow directions. Till blankets and veneers are found on the slopes further to the northeast, while the higher ridge tops have been scoured to bedrock.

Prior to glacial retreat, damming of meltwater by the ice sheet produced extensive glacial lakes in the Liard valley floor. Fine-grained glaciolacustrine deposits underlying glaciofluvial outwash are exposed along the banks of the Liard River immediately south of the town of Watson Lake and just upstream of the mouth of Watson Creek.

As the ice sheet down-wasted and retreated to the northwest, vast amounts of meltwater deposited outwash plains of sand and gravel up to 30 m thick along the valley floor currently occupied by the Liard River. Extensive ice stagnation during deglaciation left behind blocks of ice that became buried by the outwash. The buried ice blocks have subsequently melted out leaving steep sided depressions and the distinctive pitted, hummocky terrain around Upper Liard, Lucky Lake and the town of Watson Lake. The meltwater also carved deep meltwater channels through bedrock in various locations north and northeast of town.

KEY TO INTERPRETING SURFICIAL GEOLOGY MAP LABELS

Surficial geology polygons are labeled with a composite group of letters, which are arranged so that each letter position represents a particular characteristic of the terrain, including some or all of the following: texture, type of surficial material, surface expression, geomorphologic process, and activity state qualifiers. There may also be one or several surfical geology units incorporated in a polygon label. All labelling conventions are based on the British Columbia terrain classification system (Howes and Kenk, 1997).

In the sample label below, the characteristic that each letter represents is identified by the upper case type directly below each letter. For further details on each characteristic, refer to the appropriate sections of the legend.

This label indicates that the polygon is dominantly covered by muddy (m) sandy (s) pebbly (p) active (A) floodplain (FAp) with lesser amounts of flat-lying (p) and terraced (t) silty clay (zc) glaciolacustrine (LG) deposits, all of which is modified by thermokarst (e) permafrost (X) processes, gullying (V) and beaver damming (Q), and is underlain by gently dipping (j) phyllite (ph) bedrock (R).

mspFAp / zcLGpt-XeVQ \ phRj

tertiary TEXTURE 1
secondary TEXTURE 1
primary TEXTURE 1
SURFICIAL MATERIAL 1
QUALIFIER (activity) 1
SURFACE EXPRESSION 1
DELIMITER
secondary TEXTURE 2
primary TEXTURE 2
SURFICIAL MATERIAL 2
QUALIFIER (glacial) 2
primary SURFACE EXPRESSION 2
secondary SURFACE EXPRESSION 2
primary GEOMORPHOLOGICAL PROCESS
primary geomorphological PROCESS SUBCLASS
secondary GEOMORPHOLOGICAL PROCESS
tertiary GEOMORPHOLOGICAL PROCESS
STRATIGRAPHIC SYMBOL
BEDROCK SUBCLASS
underlying SURFICIAL MATERIAL 3
SURFACE EXPRESSION 3

QUALIFIERS

Qualifier symbols are used to indicate a glacial mode of surficial material formation, or the activity status of a surficial material or geomorphological process. Qualifier symbols are denoted by an upper case superscript that follows the surficial material symbol or the geomorphological process symbol. Up to two qualifiers may be used together.

SYMBOL	NAME	DESCRIPTION
G	glacial	used where there is direct evidence that glacier ice has controlled deposition
A	active	used where there is evidence that a surficial material is undergoing formation at the present time, or where a geomorphological process is occurring at present, unless activity is already inferred in the definition of surficial material or process
I	inactive	used where there is no evidence that a surficial material is undergoing formation at the present time, or where a geomorphological process is occurring at present, unless inactivity is already inferred in the definition of surficial material or process

DELIMITERS

Where multiple surficial materials are impossible to separate at map scale, up to three surficial materials can be listed, along with their textures and surface expressions, in order of decreasing importance. Each surficial material is separated by one of the following three delimiters:

SYMBOL	DESCRIPTION
.	components on either side of the symbol are of approximately equal proportion
/	the component in front of the symbol is more extensive than the one that follows
//	the component in front of the symbol is considerably more extensive than the one that follows

STRATIGRAPHIC SYMBOLS ("\" and "/")

Where one surficial material overlies another, the surficial materials are separated by a backward slash (\) symbol.

Where the overlying material is discontinous, but moderately extensive, a forward slash is included at the beginning of that unit (e.g., /sEv\gFt).

TEXTURE

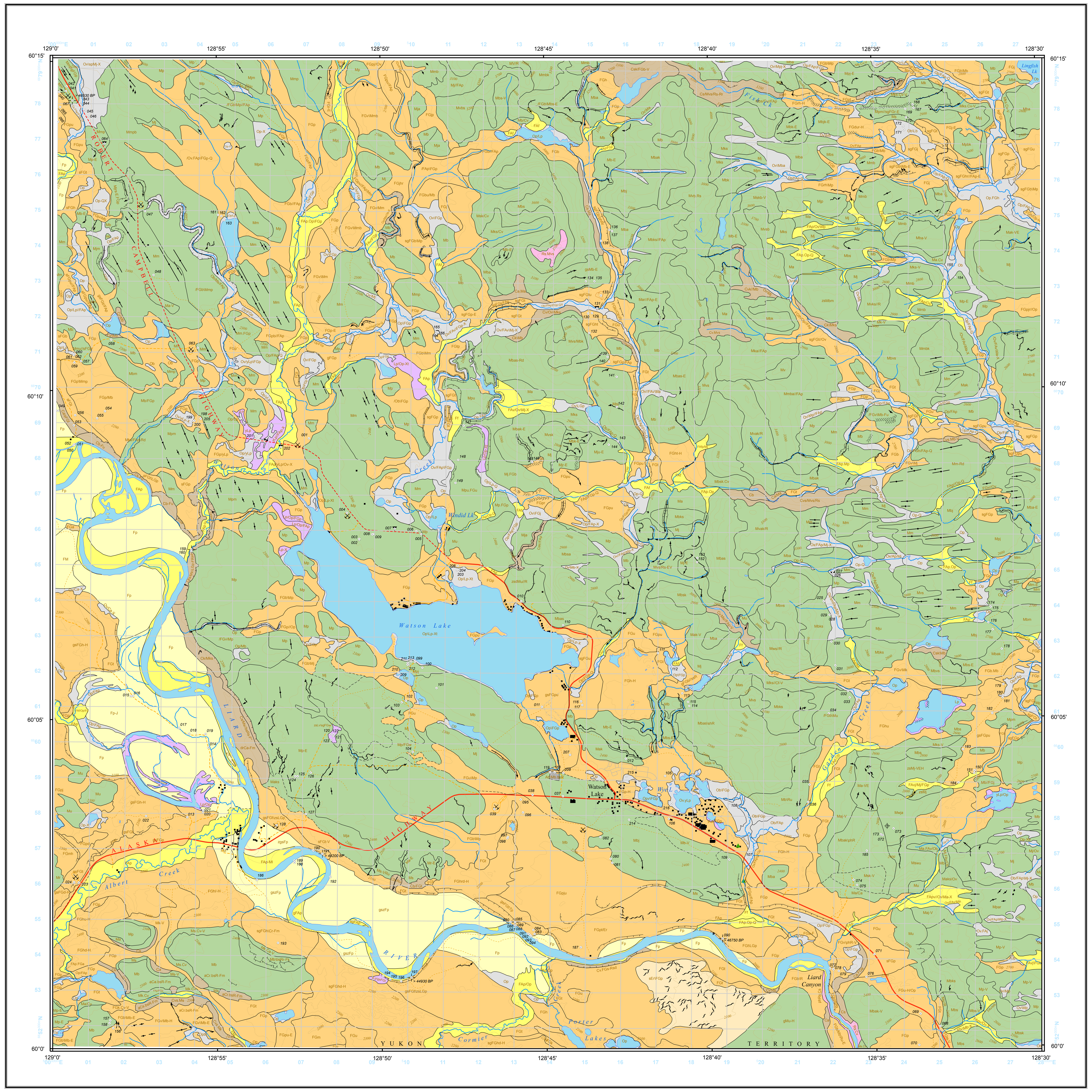
Texture refers to the size, shape (roundness) and sorting of particles in clastic sediments, and the proportion and degree of decomposition of plant fibre in organic sediments. Texture is indicated by up to three lower case letters that are listed before the surficial material designator in order of increasing importance. The use of two or three textural terms together indicates that either the various textures are intermixed or they are interstratified. Generalized textures are assigned based on representative field checking, but users should be aware that these textures can somewhat vary both laterally and vertically within a polygon.

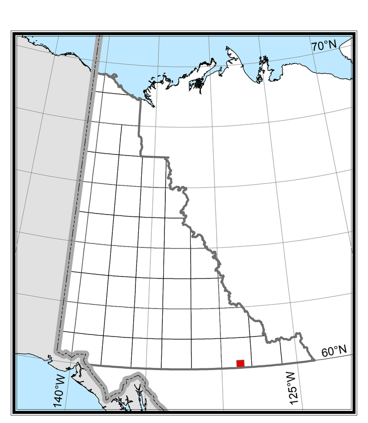
SYMBOL	NAME	SIZE (mm)	DESCRIPTION
a	blocks	> 256	angular
b	boulders	>256	rounded
c	clay	<0.002	
d	mixed fragments	>2	rounded and angular
e	fibric	fibric	poorly decomposed organic material
g	gravel	>2	rounded, mixture of two or more size ranges
h	humic		organic material, advanced decomposition
k	cobbles	64 - 256	rounded
m	mud	<0.0625	mixture of silt and clay
p	pebbles	2-64	rounded
r	rubble	2-256	angular
s	sand	0.0625 - 2	
u	mesic		organic material, intermediate decomposition
x	angular fragments	>2	mixture of angular blocks and rubble
y	shells		consists of shells and/or shell fragments
z	silt	0.002 - 0.0625	

BEDROCK SUBCLASSES

When describing bedrock, a subclass precedes the surficial material descriptor (R), instead of using a textural term as above. Bedrock subclasses used on this map include:

LABEL	NAME
bs	basalt
ph	phyllite
ss	sandstone





1:50 000-scale topographic base data
produced by
CENTRE FOR TOPOGRAPHIC INFORMATION
NATURAL RESOURCES CANADA

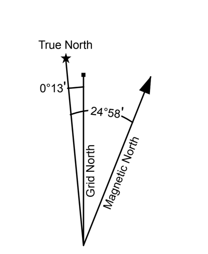
ONE THOUSAND METRE GRID
Universal Transverse Mercator Projection
North American Datum 1983
Zone 9

CONTOUR INTERVAL 100 FEET
elevations in feet above mean sea level

SURFICIAL GEOLOGY
WATSON LAKE
YUKON

SCALE 1:50 000

0 1 2 3 4 5
kilometres



Use diagram to obtain numerical values
APPROXIMATE MEAN DECLINATION 2005
FOR CENTRE OF MAP: 24º 58' E
Annual change decreasing 18.4'

105A/6 MIDDLE CANYON	105A/7 TOM LAKE	105A/8 SUNRISE CREEK
105A/3 DODO LAKES	105A/2 **THIS MAP**	105A/1 BLIND LAKE
104P/14 OLD FADDY LAKE	104P/15 LUTZ CREEK	104P/16 LOWER POST

SURFICIAL MATERIALS

Surficial materials are non-lithified, unconsolidated sediments. They are produced by weathering, sediment deposition, biological accumulation, human and volcanic activity. In general, surficial materials are of relatively young geological age and they constitute the parent material of most (pedological) soils. On the map, surficial materials form the core of the polygon label. They are symbolized with a single upper case letter, with texture written to the left, and surface expression to the right. If actual activity state is different than the assumed activity state (indicated in brackets next to the surficial material name below), a qualifier A (active) or I (inactive) must be used as a superscript following the surficial material designator. Note that a single polygon will be coloured only by the dominant surficial material, but other materials may exist in that unit.

A — Anthropogenic (A): surficial materials so modified by human activities that their original physical properties (e.g., structure, cohesion, compaction) have been drastically altered. These materials commonly have a wide range of textures. They are typically formed by the removal of material from an original site followed by redeposition elsewhere. Includes landfills and tailings.

C — Colluvium(A): materials that have reached their present positions as a result of direct, gravity-induced mass movement involving no agent of transportation such as water or ice, although the moving material may have contained water and/or ice. Generally consists of massive to moderately well stratified, non-sorted to poorly sorted sediments with any range of particle sizes from clay to boulders and blocks. Includes landslide debris, talus slopes and weathered mantles of till or bedrock.

E — Eolian (I): materials transported and deposited by wind action. Generally consists of medium to fine sand and coarse silt that is well sorted, non-compacted, and may contain internal structures such as cross-bedding or ripple laminae, or may be massive.
A thin veneer of silty loess (zEvw) between 5 and 30 cm thick is widespread throughout the map area over till and glaciofluvial deposits, especially in hollows and depressions. Inactive sand dune fields (sEr) are found immediately north and south of the Liard River, just east of Porter Lakes.

F, F^A — Fluvial (I): materials transported and deposited by streams and rivers. Deposits generally consist of gravel and/or sand and/or silt (and rarely, clay). Gravel is typically rounded and contains interstitial sand. Fluvial sediments are commonly moderately to well sorted and display stratification. Includes floodplain, delta, fluvial terrace and fan deposits.

F^G — Glaciofluvial (I): materials that exhibit clear evidence of having been deposited by glacial meltwater streams either directly in front of, or in contact with, glacier ice. Materials typically range from non-sorted and non-bedded gravel made up of a wide range of particle sizes, to moderately to well sorted, stratified gravel; flow tills may occur in some deposits. Hummocky or irregular terrain may be present and is indicative of collapse of the material due to melting of supporting ice. Kettles may occur on the surface of these deposits as a result of buried or partially buried ice melting out. Includes pitted outwash plains, kames and eskers.

M — Till (I): morainal material deposited directly by glacier ice without modification by any other agent of transportation. Morainal material can be transported beneath, beside, on, within and in front of a glacier. The physical characteristics of till deposits are highly variable and depend upon both the source of material incorporated by the glacier and the mode of deposition. In general, till consists of well compacted to non-compacted material that is non-stratified and contains a heterogeneous mixture of particle sizes, commonly in a matrix of sand, silt and clay.

L — Lacustrine (I): sediments that have settled in bodies of standing fresh water either from suspension or from underwater gravity flows, such as turbidity currents. Lacustrine sediments can also accumulate along lake margins through the action of waves. Sediments commonly consist of stratified fine sand, silt and/or clay deposited on the lake bed from suspension, or moderately to well sorted, stratified sand and coarser materials that are beach and other littoral sediments transported and deposited by wave action.

L^G — Glaciolacustrine (I): lacustrine materials deposited in or along the margins of glacial (ice-dammed) lakes, including sediments that were released by the melting of floating ice. Glaciolacustrine sediments include lake bed sediments consisting of stratified fine sand, silt and/or clay; they commonly contain ice-rafted stones and lenses of till and/or glaciofluvial material. Slump structures and/or their topographic expression, such as hummocky or irregular terrain, may be present and are indicative of collapse of the material due to melting of supporting ice. Kettles may occur on the surface of lake bed sediments as a result of the melting of buried or partially buried ice. A second type of glaciolacustrine deposite occurs as moderately sorted to well sorted, stratified sand and coarser beach sediments transported and deposited by wave action along the margins of glacial lakes.

O — Organic (A): sediments composed largely of organic materials resulting from the accumulation of vegetative matter; they contain at least 30% organic matter by weight (17% or more organic carbon). Organic materials are commonly saturated with water and consist mainly of the accumulated remains of mosses, sedges, or other hydrophytic vegetation in wetland settings.

R — Bedrock: Areas with bedrock outcrops, which may or may not be covered by a thin mantle (< 10 cm) of unconsolidated till, colluvium or organic materials.

SURFACE EXPRESSION

Surface expression refers to the form (assemblage of slopes) and pattern of forms expressed by a surficial material at the land surface. This three-dimensional shape of the material is equivalent to 'landform' used in a non-genetic sense (e.g., ridges, plain). Surface expression symbols also describe the manner in which unconsolidated surficial materials relate to the underlying substrate (e.g., veneer). Surface expression is indicated by up to three lower case letters, placed immediately following the surficial material designator, listed in order of decreasing extent.

a - Moderate slope: unidirectional (planar) surface; 16-26° (27-50%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

b - Blanket: a layer of unconsolidated material thick enough (>1 m) to mask minor irregularities of the surface of the underlying material, but still conforms to the general underlying topography; outcrops of the underlying unit are rare.

c - Cone: a cone or sector of a cone, mostly steeper than 15° (26%); longitudinal profile is smooth and straight, or slightly concave/convex; typically applied to talus cones.

d - Depression: circular or irregular area of lower elevation (hollow) than the surrounding terrain, >2 m deep, delimited by an abrupt break in slope steeper than the surrounding terrain; commonly applied to kettle holes and pitted outwash plains in glaciofluvial materials.

f - Fan: sector of a cone with a slope gradient less than 15° (26%) from apex to toe; longtitudinal profile is smooth and straight, or slightly concave/convex.

h - Hummock: steep sided hillock(s) and hollow(s) with multidirectional slopes dominantly between 15-35° (26-70%) if composed of unconsolidated materials, whereas bedrock slopes may be steeper; local relief >1 m; in plan, an assemblage of non-linear, generally chaotic forms that are rounded or irregular in cross-profile; commonly applied to knob-and-kettle glaciofluvial terrain.

j - Gentle slope: unidirectional (planar) surface; 4-15° (7-26%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

k - Moderately steep slope: unidirectional (planar) surface; 27-35° (50-70%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m.

m - Rolling: elongate hillock(s); slopes dominantly between 3-15° (5-26%); local relief >1 m; in plan, an assemblage of parallel or sub-parallel linear forms with subdued relief (commonly applied to bedrock ridges and fluted or streamlined till plains).

p - Plain: a level or very gently sloping, unidirectional (planar) surface with slopes 0-3° (0-5%); relief of local surface irregularities generally <1 m; applied to (glacio)fluvial floodplains, organic deposits, lacustrine deposits and till plains.

r - Ridge: elongate hillock(s) with slopes dominantly 15-35° (26-70%) if composed of unconsolidated materials; bedrock slopes may be steeper; local relief is >1 m; in plan, an assemblage of parallel or sub-parallel linear forms; commonly applied to drumlinized till plains, eskers, morainal ridges, crevasse fillings and ridged bedrock.

s - Steep slope: unidirectional (planar) surface; >35° (70%) slope; longitudinal profile smooth and straight, or slightly concave/convex; relief of local surface irregularities generally <1 m; bedrock slopes may be more irregular; commonly applied to terrace scarps, gully side walls and bedrock cliffs.

t - Terrace: a single or assemblage of step-like forms where each step-like form consists of a scarp face and a horizontal or gently inclined surface above it; applied to fluvial and lacustrine terraces and stepped bedrock topography.

u - Undulating: gently sloping hillock(s) and hollow(s) with multidirectional slopes up to 15° (26%); local relief >1 m; in plan, an assemblage of non-linear, generally chaotic forms that are rounded or irregular in cross-profile; commonly applied to till plains, sand dunes and kame topography.

v - Veneer: a layer of unconsolidated materials too thin to mask the minor irregularities of the surface of the underlying material; 10 cm - 1m in thick; commonly applied to eolian/loess veneers and colluvial veneers.

w - Mantle of variable thickness: a layer or discontinuous layer of surficial material of variable thickness (0-3 m) that fills or partly fills depressions in an irregular substrate.

x - Thin veneer: a very thin layer of unconsolidated material, 2-20 cm thick.

SYMBOL LEGEND

building
campground
airstrip
seaplane base
tank
tower
lake
stream
topographical contour
trail
highway, paved
main road, loose surface
secondary road (paved, loose surface)
street (paved, loose surface)

field observation site — site number (04WLXXX)
observation of frozen ground
C14 radiocarbon dated wood sample — years
stratigraphic section site
gravel pit
kettle hole
landslide headwall and track
sand dunes
streamlined landform (drumlins, flutings, grooves)
terrain boundary (defined, approximate)
meltwater channel
scarp
esker
tension crack

GEOMORPHOLOGICAL PROCESSES

Geomorphological processes are natural mechanisms of weathering, erosion and deposition that result in the modification of the surficial materials and landforms at the earth's surface. Unless a qualifier (A (active) or I (inactive)) is used, all processes are assumed to be active, except for deglacial processes. Process is indicated by up to three upper case letters, listed in order of decreasing importance, placed after the surface expression symbol, and separated from the surface expression by a dash (-).

Subclasses can be used to provide more specific information about a general geomorophological process, and are represented by lower case letter(s) placed after the related process designator. Up to three subclasses can be attached to each process. Process subclasses used on this map are defined with the related process below.

EROSIONAL PROCESSES

V - Gully erosion: running water, mass movement and/or snow avalanching, resulting in the formation of parallel and sub-parallel long, narrow ravines.

FLUVIAL PROCESSES

I - Irregularly sinuous channel: a clearly defined main channel displaying irregular turns and bends without repetition of similar features; backchannels may be common, and minor side channels and a few bars and islands may be present, but regular and irregular meanders are absent.

J - Anastomosing channel: a channel zone where channels diverge and converge around many islands. The islands are vegetated and have surfaces that are relatively far above mean maximum discharge levels. Some channels are dry at moderate or low flows.

M - Meandering channel: a clearly defined channel characterized by a regular and repeated pattern of bends with relatively uniform amplitude and wave length.

Q - Beaver damming: interruption of regular fluvial transport by beaver dams leading to widespread and repeated ponding.

MASS MOVEMENT PROCESSES

F - Slow mass movements: slow downslope movement of masses of cohesive or non-cohesive surficial material and/or bedrock by creeping, flowing or sliding.

Subclasses: (k) tension cracks - fissures commonly near the crest of a slope; (u) slump: sliding of internally cohesive mass of surficial material along a slip plane that is concave upward or planar.

R - Rapid mass movements: rapid downslope movement by falling, rolling, sliding or flowing of dry, moist or saturated debris derived from surficial material and/or bedrock.

Subclasses: (") initiation zone - headscarps of debris slides or earthflows and source areas for rockfall and debris flows; (d) debris flow - rapid flow of saturated debris; (m, u) slump - sliding of internally cohesive masses of bedrock (m) or surficial material (u) along a slip plane that is concave upward or planar; (r) rockslide - sliding mass of disintegrating bedrock; (s) debris slide - sliding mass of disintegrating surficial material.

PERIGLACIAL PROCESSES

C - Cryoturbation: movement of surficial materials by heaving and/or churning due to frost action (repeated freezing and thawing).

X - Permafrost processes: processes controlled by the presence of permafrost, and permafrost aggradation or degradation.

Subclasses (e) - thermokarst: depressions created by melting of ice-rich permafrost due to heat transfer from water bodies; (t) - surface depressions created by the thaw of ice-rich permafrost and resulting soil subsidence.

DEGLACIAL PROCESSES

E - Channeled by meltwater: erosion and channel formation by meltwater alongside, beneath, or in front of a glacier.

H - Kettled: depressions in surficial materials resulting from the melting of buried glacier ice.

SELECTED REFERENCES

Anderson, L., Abbott, M.B., Finney, B. and Edwards, M.E., 2002. The Holocene lake-level history of Marcella Lake, southern Yukon Territory, Canada. Geological Society of America, Northeastern Section, 37th annual meeting, Springfield, MA, Session No. 19 Program Abstract.

Gabrielse, H., 1967. Geology, Watson Lake, Yukon Territory. Geological Survey of Canada Map 19-1966, 1:250 000 scale.

Howes, D.E. and Kenk, E. (ed.), 1997. Terrain classification system for British Columbia (version 2). Province of British Columbia: Resource Inventory Branch, Ministry of Environment, Lands and Parks; Recreational Fisheries Branch, Ministry of Environment; and Surveys and Mapping Branch, Ministry of Crown Lands. (Available online at http://srmwww.gov.bc.ca/risc/pubs/teecolo/terclass/).

Jackson, L.E., Jr., Ward, B., Duk-Rodkin, A. and Hughes, O.L., 1991. The Last Cordilleran Ice Sheet in Southern Yukon Territory. Géographie physique et Quaternaire, vol. 45, no. 3, p. 341-354.

Klassen, R.W. and Morison, S.R., 1981. Surficial geology, Watson Lake, Yukon Territory. Geological Survey of Canada Map 21-1981, 1:250 000 scale.

Klassen, R.W., 1987. The Tertiary Pleistocene stratigraphy of the Liard Plain, southeastern Yukon Territory. Geological Survey of Canada Paper 86-17, p. 16.

Lavkulich, L.M., Walmsley, M.E. and Beale, R.L., 1973. Physical environmental studies, Watson Lake area, Yukon Territory. Indian and Northern Affairs Canada, Arctic Land Use Research Program (ALUR) Final Report 72-73-01.

Lipovsky, P.S. and McKenna, K., 2005. Local-scale biophysical mapping for integrated resource management, Watson Lake area (NTS 105A/2), Yukon. Yukon Geological Survey, Energy, Mines and Resources, Yukon Government, Open File 2005-6, report and CD-ROM, 74 p.

McKenna, K. and Lipovsky, P.S., 2005. Biophysical map of Watson Lake area (NTS 105A/2), Yukon (1: 50 000 scale). Yukon Geological Survey, Energy, Mines and Resources, Yukon Government, Open File 2005-8.

Ryder, J.M. and Howes, D.E., 1986. Terrain information: a user's guide to terrain maps in British Columbia. Government of British Columbia. (Available online at http://srmwww.gov.bc.ca/terrain/inventory/guide/index.html).

ACKNOWLEDGEMENTS

This work was funded in part by the Knowledge and Innovation Fund of the Department of Indian and Northern Affairs Canada. Mapping would not have been possible without the invaluable assistance of Rob Legare at the Forest Management Branch (Yukon Energy, Mines and Resources), as well as Jan Adamczewski and Riley Brodhagen at the Watson Lake Fish and Wildlife Branch (Yukon Environment).

RECOMMENDED CITATION

Lipovsky, P.S., McKenna, K. and Huscroft, C.A., 2005. Surficial geology of Watson Lake (NTS 105A/2), Yukon (1: 50 000 scale), Yukon Geological Survey, Energy, Mines and Resources, Yukon Government, Open File 2005-7.

Digital cartography and drafting by P.S. Lipovsky using ArcGIS 9.0. Mapping based on hard-copy and soft-copy (using MicroStation Diap Viewer) air photo interpretation using 1:40 000-scale 1998/1999 photos. Field checking was performed in summer 2004.

Any revisions or additional geological information known to the user would be welcomed by the Yukon Geological Survey.

Paper copies of this map, the accompanying report and Yukon MINFILE may be purchased from Geoscience Information and Sales, c/o Whitehorse Mining Recorder, Energy, Mines and Resources, Yukon Government, Room 102 - 300 Main St., Whitehorse, Yukon, Y1A 2B5. Ph. 867-667-5200, Fx. 867-667-5150, Email geosales@gov.yk.ca.

A digital PDF (Portable Document File) file of this map may be downloaded free of charge from the Yukon Geological Survey website: http://www.geology.gov.yk.ca.

Yukon Geological Survey
Energy, Mines and Resources
Government of Yukon

Open File 2005-7

Surficial Geology of Watson Lake Area (NTS 105A/2), Yukon (1:50 000 scale)

by

P.S. Lipovsky[1], K. McKenna[2], and C.A. Huscroft[1]

[1] Yukon Geological Survey
[2] Cryogeographic Consulting

Appendix 3. Grain Size Analyses

PARTICLE SIZE DISTRIBUTION

ASTM D6913

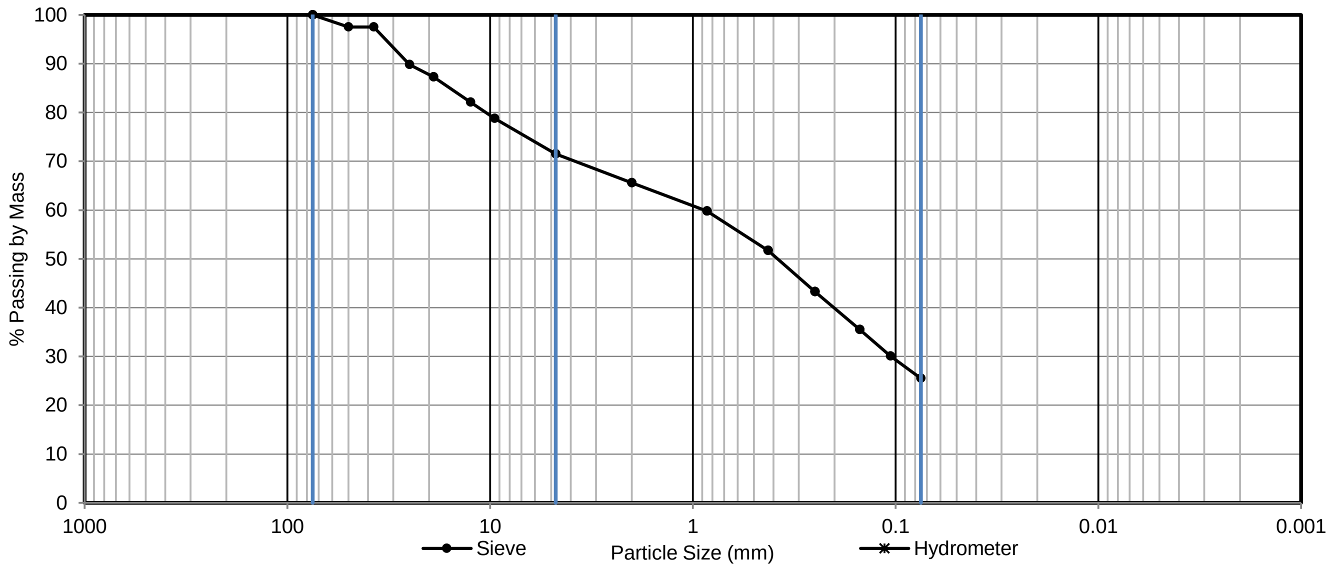
Method B

Test Request #	B23-063	Project Number:	20148488-4000
Client:	Yukon Government Water Resources Branch	Project Location:	Watson Lake, Yukon
Project Name:	Watson Lake Aquifer Mapping	Sample Location:	YOWN 2208
Source:		Sample No.:	10273-1
Soil Description:		Type:	GS
		Depth (m):	3.96 - 6.10

Specimen Reference	NA	Specimen Depth (m):	NA	Date of Test	3/2/2023
Specimen Description	NA				

Grain Size Distribution (%)

BOULDER	COBBLE	GRAVEL		SAND			FINES (Silt, Clay)
		Coarse	Fine	Coarse	Medium	Fine	
		28.5		46.0			25.5



Sieve			Hydrometer Sedimentation	
Sieve No.	Particle Size mm	% Passing	Particle Size mm	% Passing
3"	75	100.0		
2"	50	97.5		
1 1/2"	37.5	97.5		
1"	25	89.8		
3/4"	19	87.3		
1/2"	12.5	82.1		
3/8"	9.5	78.8		
#4	4.75	71.5		
#10	2	65.6		
#20	0.85	59.8		
#40	0.425	51.7		
#60	0.25	43.3		
#100	0.15	35.5		
#140	0.106	30.1		
#200	0.075	25.5	0.005 mm	
			0.002 mm	
			D60	0.88
			D30	0.11
			D10	
			Cu	
			Cc	

Notes:

Disclaimer:

Tested by: JPandez **Date:** 2-Mar-23 **Checked by:** JPandez **Date:** 6-Mar-23 **Reviewed by:** SJohn **Date:** 8-Mar-23

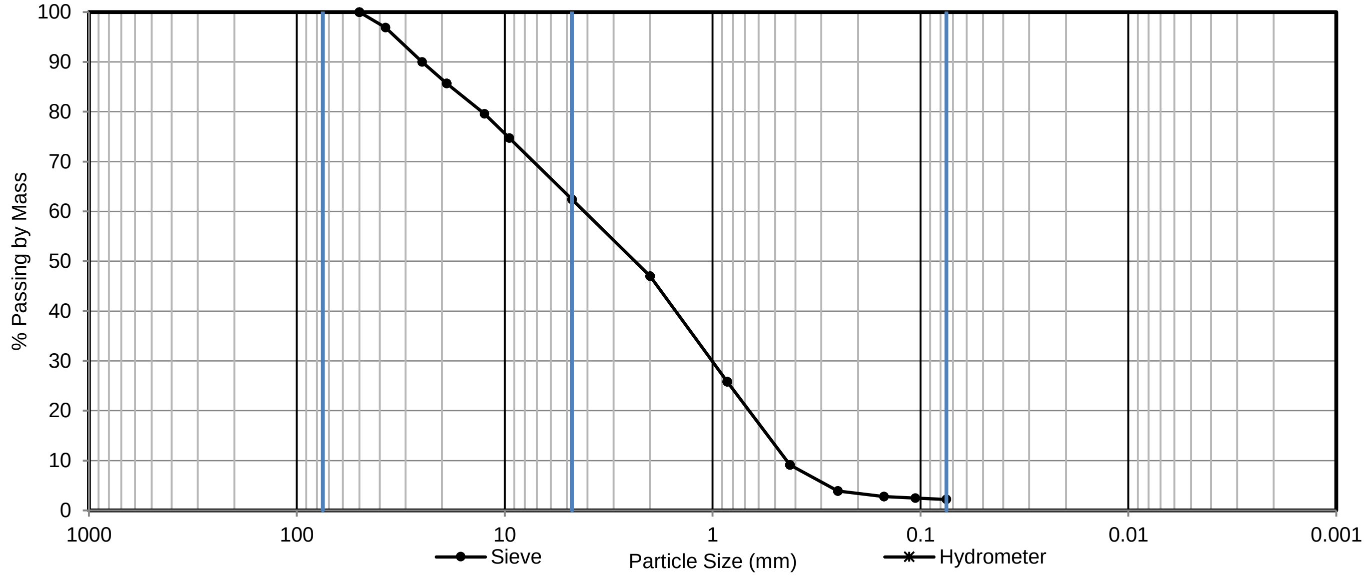
PARTICLE SIZE DISTRIBUTION

ASTM D6913
Method B

Test Request #	B23-063	Project Number:	20148488-4000
Client:	Yukon Government Water Resources Branch	Project Location:	Watson Lake, Yukon
Project Name:	Watson Lake Aquifer Mapping	Sample Location:	YOWN 2209
Source:		Sample No.:	10273-2
Soil Description:		Type:	GS
		Depth (m):	11.58 - 13.72

Specimen Reference	NA	Specimen Depth (m):	NA	Date of Test	2/28/2023
Specimen Description	NA				

Grain Size Distribution (%)			37.6		60.2			2.2
BOULDER	COBBLE	GRAVEL		SAND			FINES (Silt, Clay)
		Coarse	Fine	Coarse	Medium	Fine	



Sieve			Hydrometer Sedimentation	
Sieve No.	Particle Size mm	% Passing	Particle Size mm	% Passing
2"	50	100.0		
1 1/2"	37.5	96.9		
1"	25	90.0		
3/4"	19	85.7		
1/2"	12.5	79.6		
3/8"	9.5	74.7		
#4	4.75	62.4		
#10	2	47.0		
#20	0.85	25.8		
#40	0.425	9.1		
#60	0.25	3.9		
#100	0.15	2.8		
#140	0.106	2.5		
#200	0.075	2.2		
			0.005 mm	
			0.002 mm	
			D60	4.15
			D30	1.01
			D10	0.44
			Cu	9.40
			Cc	0.55

Notes:

Disclaimer:

The laboratory testing services reported herein have been performed in accordance with the terms of a contract with WSP's client, and with the recognized standards indicated in this report, or local industry practice. This laboratory testing services report is for the sole use of WSP's client, relates only to the sample(s) tested and does not represent any (actual or implied) interpretation or opinion regarding specification compliance or materials suitability for any specific purpose.

Tested by: KScribner **Date:** 28-Feb-23 **Checked by:** JPandez **Date:** 2-Mar-23 **Reviewed by:** SJohn **Date:** 8-Mar-23

WSP Canada Inc.
Unit 300 - 3811 North Fraser Way, Burnaby, British Columbia, V5J 5J2, Canada

[+1] 604 412 6899

PARTICLE SIZE DISTRIBUTION

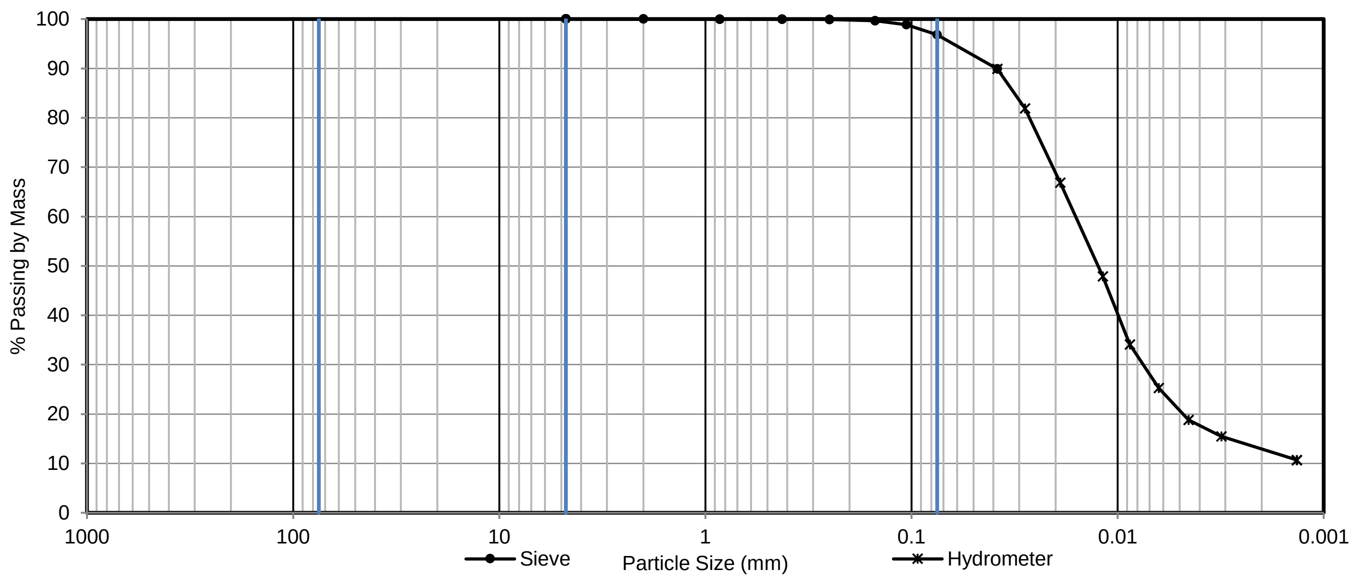
ASTM D6913 and ASTM D422

Method B

Test Request #	B23-063	Project Number:	20148488-4000
Client:	Yukon Government Water Resources Branch	Project Location:	Watson Lake, Yukon
Project Name:	Watson Lake Aquifer Mapping	Sample Location:	YOWN 2209
Source:		Sample No.:	10273-3
Soil Description:		Type:	GS
		Depth (m):	42.98 - 47.55

Specimen Reference	NA	Specimen Depth (m):	NA	Date of Test	3/1/2023
Specimen Description	NA				

Grain Size Distribution (%)			0.0		3.2			96.8
BOULDER	COBBLE	GRAVEL		SAND			FINES (Silt, Clay)
		Coarse	Fine	Coarse	Medium	Fine	



Sieve			Hydrometer Sedimentation	
Sieve No.	Particle Size mm	% Passing	Particle Size mm	% Passing
#4	4.75	100.0	0.0383	89.9
#10	2	100.0	0.0281	81.9
#20	0.85	100.0	0.0190	66.9
#40	0.425	100.0	0.0118	47.9
#60	0.25	99.9	0.0087	34.1
#100	0.15	99.6	0.0063	25.3
#140	0.106	98.8	0.0045	18.8
#200	0.075	96.8	0.0031	15.5
			0.0014	10.7
			0.005 mm	20.70
			0.002 mm	12.90
			D60	0.02
			D30	0.01
			D10	
			Cu	
			Cc	

Notes:

Disclaimer:

The laboratory testing services reported herein have been performed in accordance with the terms of a contract with WSP's client, and with the recognized standards indicated in this report, or local industry practice. This laboratory testing services report is for the sole use of WSP's client, relates only to the sample(s) tested and does not represent any (actual or implied) interpretation or opinion regarding specification compliance or materials suitability for any specific purpose.

Tested by: JPandez **Date:** 1-Mar-23 **Checked by:** JPandez **Date:** 7-Mar-23 **Reviewed by:** SJohn **Date:** 8-Mar-23

WSP Canada Inc.
Unit 300 - 3811 North Fraser Way, Burnaby, British Columbia, V5J 5J2, Canada

[+1] 604 412 6899

PARTICLE SIZE DISTRIBUTION

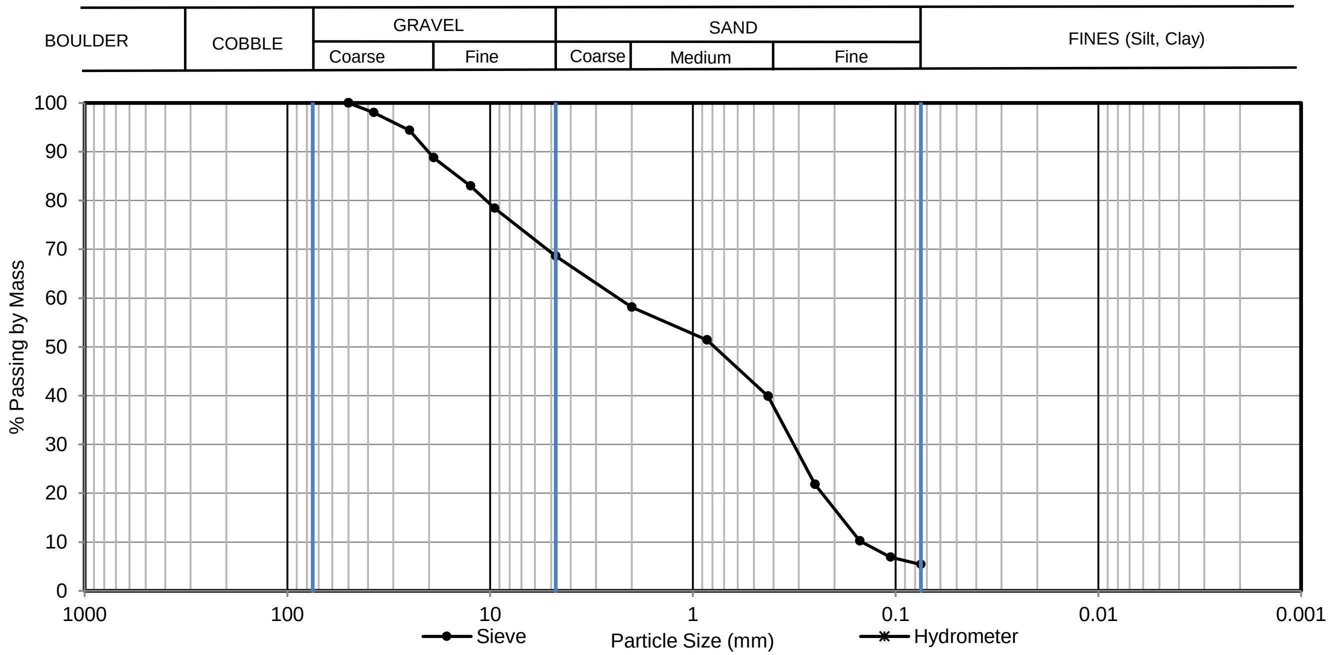
ASTM D6913

Method B

Test Request #	B23-063	Project Number:	20148488-4000
Client:	Yukon Government Water Resources Branch	Project Location:	Watson Lake, Yukon
Project Name:	Watson Lake Aquifer Mapping	Sample Location:	YOWN 2209
Source:		Sample No.:	10273-4
Soil Description:		Type:	GS
		Depth (m):	48.46 - 49.99

Specimen Reference	NA	Specimen Depth (m):	NA	Date of Test	2/28/2023
Specimen Description	NA				

Grain Size Distribution (%): 31.4 | 63.2 | 5.4



Sieve			Hydrometer Sedimentation	
Sieve No.	Particle Size mm	% Passing	Particle Size mm	% Passing
2"	50	100.0		
1 1/2"	37.5	98.0		
1"	25	94.4		
3/4"	19	88.8		
1/2"	12.5	83.0		
3/8"	9.5	78.4		
#4	4.75	68.6		
#10	2	58.1		
#20	0.85	51.4		
#40	0.425	39.9		
#60	0.25	21.8		
#100	0.15	10.2		
#140	0.106	6.9		
#200	0.075	5.4		
			0.005 mm	
			0.002 mm	
			D60	2.34
			D30	0.32
			D10	0.15
			Cu	16.00
			Cc	0.29

Notes:

Disclaimer:

The laboratory testing services reported herein have been performed in accordance with the terms of a contract with WSP's client, and with the recognized standards indicated in this report, or local industry practice. This laboratory testing services report is for the sole use of WSP's client, relates only to the sample(s) tested and does not represent any (actual or implied) interpretation or opinion regarding specification compliance or materials suitability for any specific purpose.

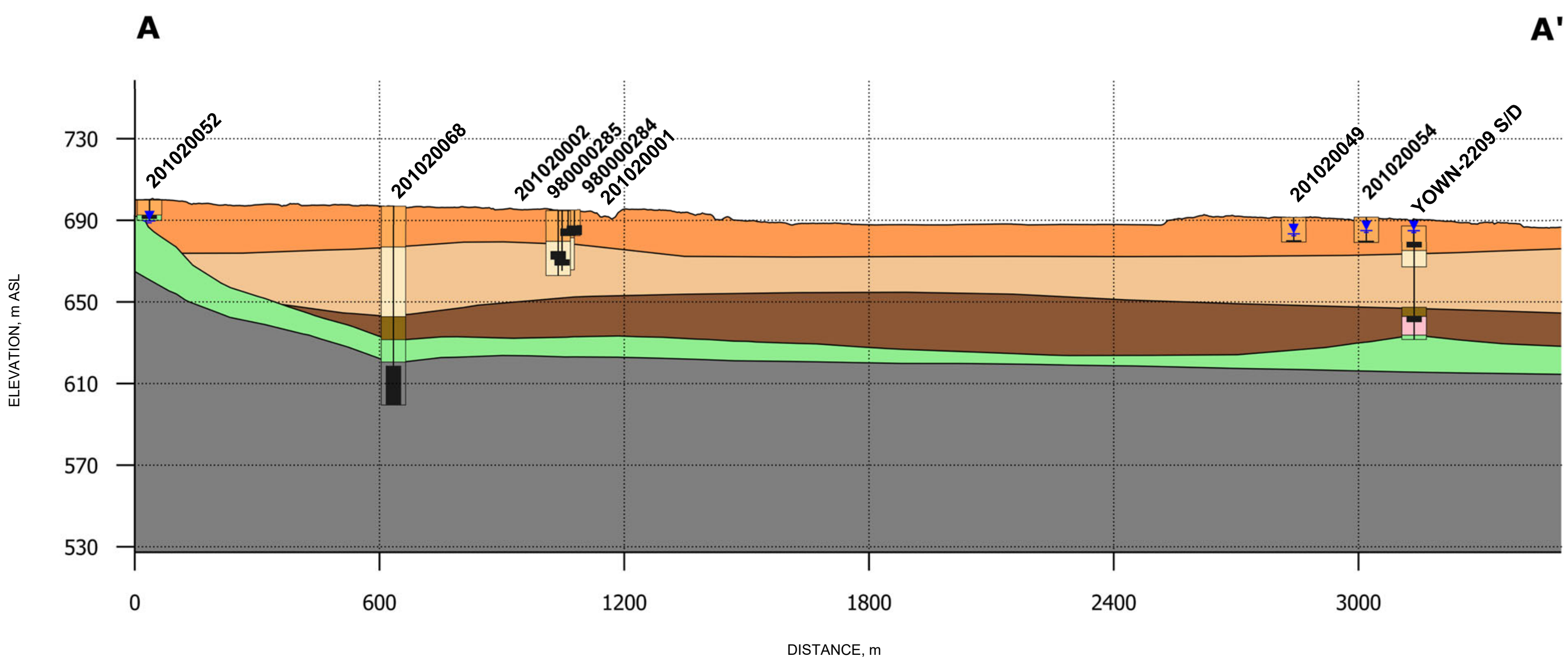
Tested by: KScribner **Date:** 28-Feb-23 **Checked by:** JPandez **Date:** 2-Mar-23 **Reviewed by:** SJohn **Date:** 8-Mar-23

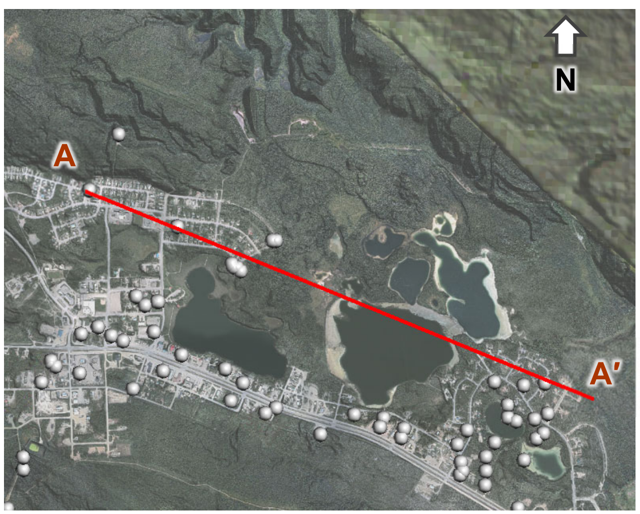
WSP Canada Inc.
Unit 300 - 3811 North Fraser Way, Burnaby, British Columbia, V5J 5J2, Canada

[+1] 604 412 6899

Rev57-27022023

Appendix 4. Hydrostratigraphic Cross-Sections





LEGEND

- BEDROCK
- TILL
- WATSON LAKE AQUITARD
- DELTAIC PACKAGE AQUIFER
- GLACIOFLUVIAL AQUIFER
- POTENTIAL DEEP SANDS AND GRAVEL AQUIFER
- SCREENED INTERVAL
- GROUNDWATER HEAD (AT TIME OF DRILLING)
- **10901000** WATER WELL LOCATION

NOTE(S)
VERTICAL EXAGGERATION 5:1

REFERENCE
WELL COMPLETION DATA, AND WATER LEVELS OBTAINED FROM YUKON WELL REGISTRY

CLIENT
YUKON GOVERNMENT
WATER RESOURCE BRANCH

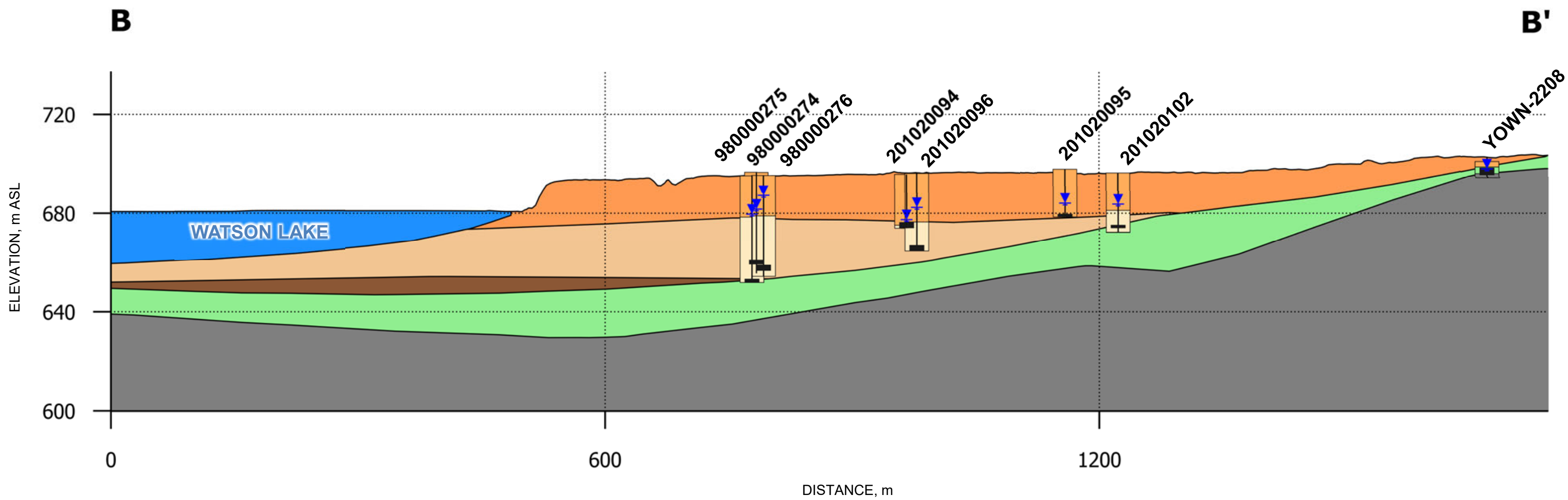
CONSULTANT

YYYY-MM-DD	2022-11-26
PREPARED	RKS
DESIGN	RKS
REVIEW	NGG
APPROVED	TR

PROJECT
WATSON LAKE AQUIFER MAPPING

TITLE
HYDROSTRATIGRAPHIC CROSS-SECTION A-A'

PROJECT No.	PHASE	Rev.	FIGURE
20148488	4000	0	App 4-2



LEGEND

- BEDROCK
- TILL
- WATSON LAKE AQUITARD
- DELTAIC PACKAGE AQUIFER
- GLACIOFLUVIAL AQUIFER
- SCREENED INTERVAL
- GROUNDWATER HEAD (AT TIME OF DRILLING)
- **10901000** WATER WELL LOCATION

NOTE(S)
VERTICAL EXAGGERATION 3:1

REFERENCE
WELL COMPLETION DATA, AND WATER LEVELS OBTAINED FROM YUKON WELL REGISTRY

CLIENT
YUKON GOVERNMENT
WATER RESOURCE BRANCH

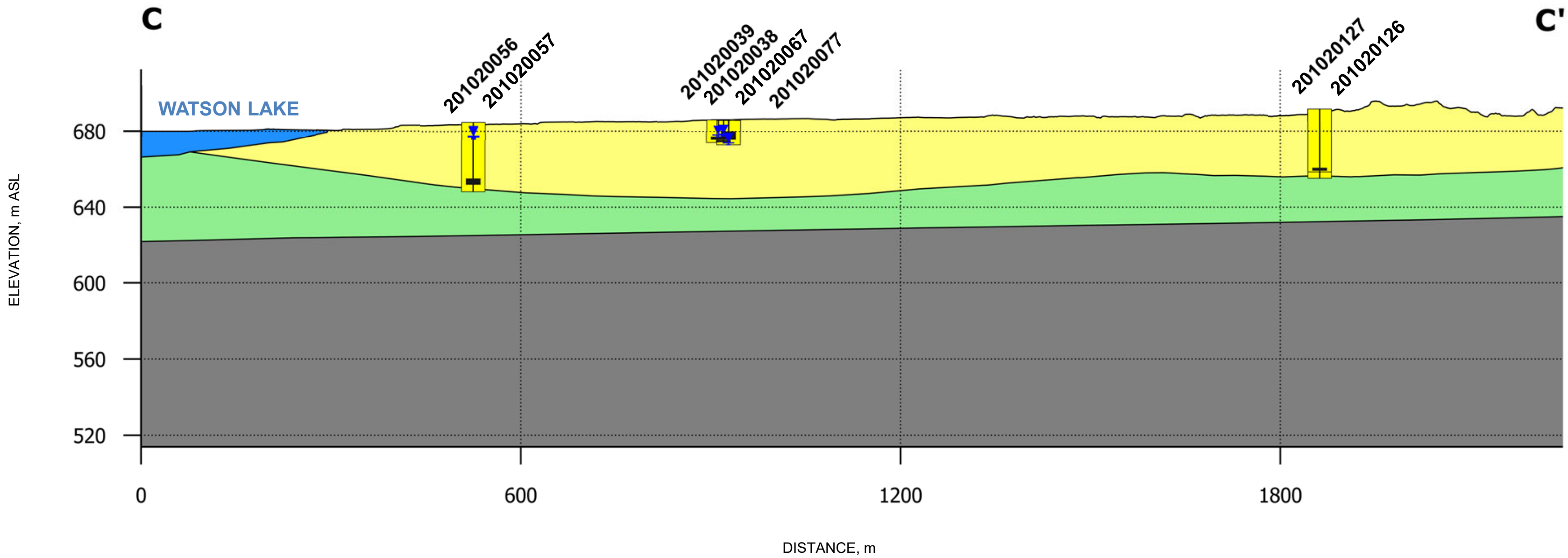
CONSULTANT

YYYY-MM-DD	2022-11-26
PREPARED	RKS
DESIGN	RKS
REVIEW	NGG
APPROVED	TR

PROJECT
WATSON LAKE AQUIFER MAPPING

TITLE
HYDROSTRATIGRAPHIC CROSS-SECTION B-B'

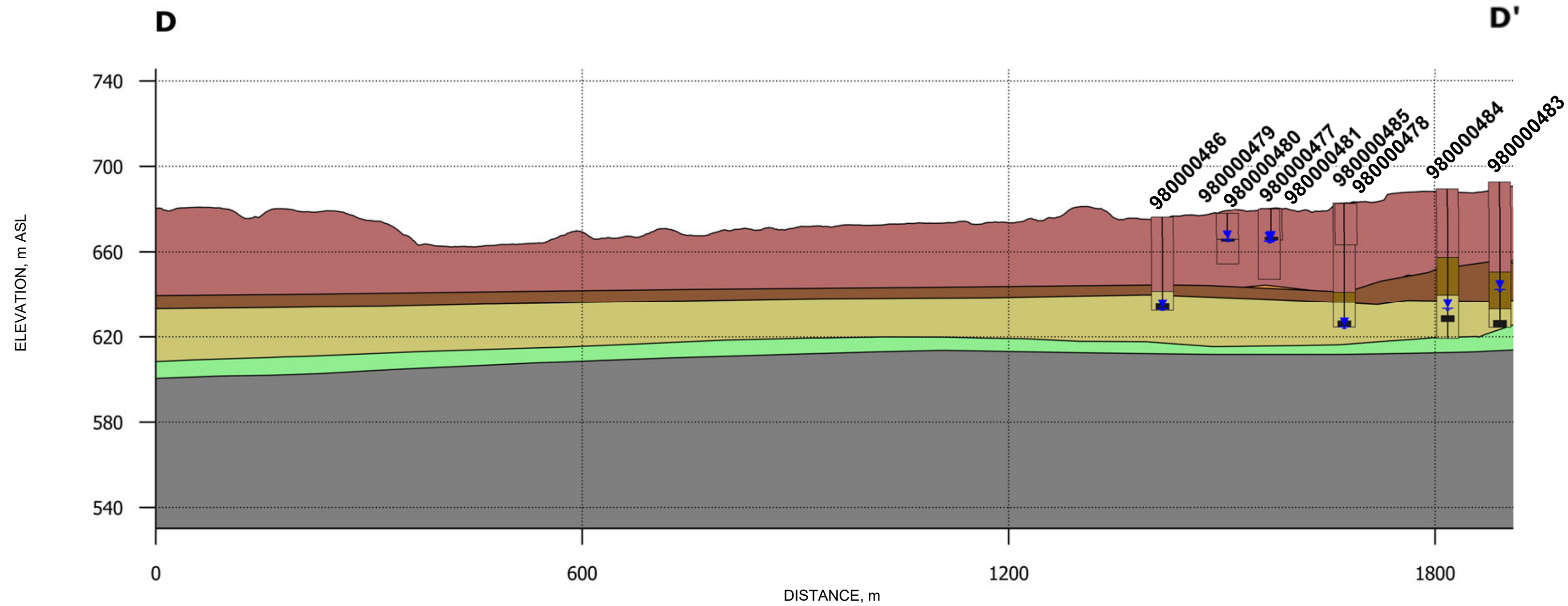
PROJECT No.	PHASE	Rev.	FIGURE
20148488	4000	0	App 4-3

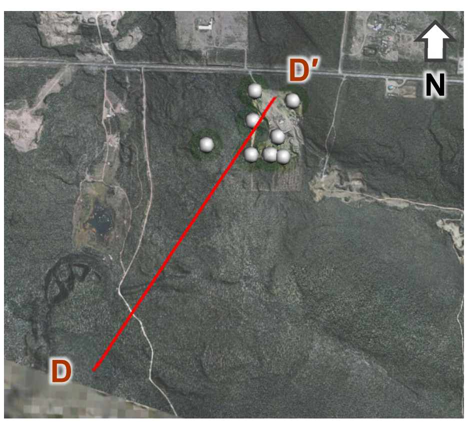


LEGEND

- BEDROCK
- TILL
- WATSON LAKE AQUITARD
- FAN AQUIFER
- SCREENED INTERVAL
- GROUNDWATER HEAD (AT TIME OF DRILLING)
- **10901000** WATER WELL LOCATION

NOTE(S)	VERTICAL EXAGGERATION 3:1
REFERENCE	WELL COMPLETION DATA, AND WATER LEVELS OBTAINED FROM YUKON WELL REGISTRY
CLIENT	YUKON GOVERNMENT WATER RESOURCE BRANCH
CONSULTANT	
YYYY-MM-DD	2022-11-26
PREPARED	RKS
DESIGN	RKS
REVIEW	NGG
APPROVED	TR
PROJECT	WATSON LAKE AQUIFER MAPPING
TITLE	**HYDROSTRATIGRAPHIC CROSS-SECTION C-C'**
PROJECT No.	20148488
PHASE	4000
Rev.	0
FIGURE	App 4-4





LEGEND

- BEDROCK
- TILL
- WATSON LAKE AQUITARD
- PONTENTIAL DEEP GLACIAL OUTWASH SANDS AND GRAVEL AQUIFER
- POTENTIAL GLACIOFLUVIAL AQUIFER (LIARD VALLEY)
- SCREENED INTERVAL
- GROUNDWATER HEAD (AT TIME OF DRILLING)
- **10901000** WATER WELL LOCATION

NOTE(S)
VERTICAL EXAGGERATION 3:1

REFERENCE
WELL COMPLETION DATA, AND WATER LEVELS OBTAINED FROM YUKON WELL REGISTRY

CLIENT
YUKON GOVERNMENT
WATER RESOURCE BRANCH

CONSULTANT

YYYY-MM-DD	2022-11-26
PREPARED	RKS
DESIGN	RKS
REVIEW	NGG
APPROVED	TR

PROJECT
WATSON LAKE AQUIFER MAPPING

TITLE
HYDROSTRATIGRAPHIC CROSS-SECTION D-D'

PROJECT No.	PHASE	Rev.	FIGURE
20148488	4000	0	App 4-5

Appendix 5. Aquifer Summary

Aquifer Summary Table

#	Name	Lithostratigraphic Unit	Descriptive Location	Vulnerability	Subtype	Material	Quality Concerns	Size (km^2)	Productivity	Demand	Artesian Conditions Noted	Observation Wells
1	Fan Aquifer	Fan Deposit	Watson Lake Airport	High	3 / 4a	Sand and gravel	None	3.7	Moderate/ High	Low	None documented	-
2	Glaciofluvial Aquifer	Glaciofluvial Deposits	Within the valley to the east of Watson Lake	High	4a	Sand, Sand and Gravel	None	12.8	Moderate/ High	Low	None documented	YOWN-2209 S
3	Deltaic Package Aquifer	Glaciolacustrine Deltaic Package	Within the valley to the east of Watson Lake underlying the Glaciofluvial Aquifer	High	4a	Sand, Sand and Gravel	Manganese and Iron exceed GCDWQG AO	12.8	Moderate/ High	Low	None documented	-

The aquifer classifications in the above table are based on the BC aquifer classification system is outlined in the Guide to Using the BC Aquifer Classification Maps for the Protection and Management of Groundwater, issued by the BC Ministry of Water Land and Air Protection, June 2002 (Bernardinucci and Ronneseth, 2002).

Aquifer subtypes are described in Wei, M., D. Allen, A. Kohut, S. Grasby, K. Ronneseth and B. Turner, 2009. Understanding the Types of Aquifers in the Canadian Cordillera Hydrogeological Region to Better Manage and Protect Groundwater. Streamline Watershed Management Bulletin Vol. 13, No.1, Fall 2009.

- 3: Alluvial or colluvial fan sand and gravel aquifers typically occur at or near the base of mountain slopes, either along the side of valley bottoms, or if formed during the last period of glaciation, raised above the valley bottoms.
- 4a: Unconfined glacio-fluvial outwash or ice contact sand and gravel aquifers generally formed near or at the end of the last period of glaciation.

Appendix 6. Aquifer Shapefiles

Shapefiles for the Fan Aquifer, Glaciofluvial Aquifer, Deltaic Package Aquifer are provided digitally in an attached folder.

Appendix 7. Aquifer Well-Correlation

For Aquifer-Well correlation sheet of the Watson Lake area, reference the attached csv file entitled “Aquifer_Well_Correlation_WatsonLake_04December2022.csv”.

Appendix 8. Interpreted Hydrostratigraphy

For a summary of the hydrostratigraphic contacts for each well, reference the attached csv file entitled “Interpreted_Hydrostratigraphic_Units_WatsonLake_04December2022.csv”.