

# Yukon Permafrost Database: A new baseline data resource

Panya S. Lipovsky\*, Jennifer K. Humphries, Emilie T. Stewart-Jones and Derek C. Cronmiller  
Yukon Geological Survey

Lipovsky, P.S., Humphries, J.K., Stewart-Jones, E.T. and Cronmiller, D.C., 2022. Yukon Permafrost Database: A new baseline data resource. *In: Yukon Exploration and Geology 2021*, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 37–49.

## Abstract

The Yukon Geological Survey (YGS) has compiled available geotechnical and ground temperature data and related literature from government, industry and other contributors into the Yukon Permafrost Database. This paper reviews the database development process and structure, provides a snapshot of the primary datasets that have been loaded to date and discusses some of its limitations. The database is publicly accessible from an online portal (<https://yukon.ca/en/yukon-permafrost>) where data may be explored interactively in web maps, tables, and time series and ground temperature envelope graphics. Database contents are also available for download in a variety of formats. The Yukon Permafrost Database provides easily accessible data on permafrost distribution and thermal regime to support the assessment of thaw-related hazard and risk, and works towards the integration of disparate permafrost data at a territorial scale. The database will be maintained and updated regularly and YGS welcomes data contributions from government, industry and academic researchers to facilitate ongoing improvements to our collective knowledge of permafrost in Yukon.

\* [Panya.Lipovsky@yukon.ca](mailto:Panya.Lipovsky@yukon.ca)

## Introduction

Permafrost degradation is impacting communities and public infrastructure at an increasing rate, often with costly consequences. *Our Clean Future: A Yukon Strategy for Climate Change, Energy and a Green Economy* (Government of Yukon, 2020) identifies permafrost thaw as one of the major climate change-related issues in Yukon and lists several actions that aim to address it. The most critical risks of permafrost thaw are related to ground movements (e.g., landslides and subsidence) which may increase maintenance costs for affected infrastructure such as roads and buildings, sever transportation corridors, and/or cause loss of life. Other risks associated with permafrost thaw include the release of greenhouse gases (Schuur et al., 2015) and contaminants such as mercury into the ecosystem (Schaefer et al., 2020).

Despite the importance of thawing permafrost, data on the distribution and character of permafrost to support risk assessments across Yukon have not been easily accessible to date. Permafrost information has largely existed as disparate datasets held by numerous researchers, government organizations, industry and consultants. These include data from instrumented boreholes owned by university researchers, unpublished geological survey data (both Yukon and Canada), and geotechnical data collected under Government of Yukon contracts in communities and along road infrastructure. Much of the latter previously resided only as paper reports held by various departments.

Since permafrost data are a critical underpinning of any thaw-related risk assessment, a first step toward improving access to these data has been to develop a centralized permafrost database for Yukon. Such a database has been recognized as a gap for many years, and the *Our Clean Future* strategy catalyzed its development.

This paper describes how the database was developed and outlines its organization and structure. It also provides a summary of the primary datasets that have been loaded to date and identifies some limitations of use.

## Database development process

YGS is well-positioned to lead the development of the Yukon Permafrost Database (the Database) given its strong history of managing and serving public geoscience data. The initial phase of database development began in 2019 with a review and evaluation of existing permafrost database structures, platforms, nomenclature standards, and quality assurance and quality control (QA/QC) processes. The Mackenzie Valley Geotechnical Database published by the Geological Survey of Canada (GSC; Smith et al., 2005) was selected as the initial template to modify and build upon for the geotechnical component of the Yukon Permafrost Database. Carleton University's Cryospheric Observations Longterm Database and Storage System (COLDASS; Carleton University, 2021) was used as the initial template to modify and build upon for the temperature component of the database. Drawing on these pre-existing works saved significant time and resources toward initial database design.

Database development occurred in consultation with a local working group comprising various stakeholders who collect and use permafrost data in the territory: YG Energy, Mines and Resources (Yukon Geological Survey, Assessment and Abandoned Mines, and Land Management branches); YG Highways and Public Works (Transportation Engineering and Property Management branches); YG Community Services (Land Development and Infrastructure Development branches); YG Environment (Water Resources branch and Climate Change Secretariat); and YukonU Research Centre (Yukon University).

YGS also engaged with a variety of other agencies outside Yukon who are involved in similar initiatives to manage permafrost data: Natural Sciences and Engineering Research Council (NSERC) PermafrostNet (2021); the Geological Survey of Canada (Permafrost Information Network, 2021; O'Neill et al., 2018); and the Northwest Territories Geological Survey (2021). This collaboration offered great benefits to all parties by minimizing duplication, sharing standards and methodologies, and ensuring interoperability and consistency where possible.

Data modeling (i.e., design of tables and their relationships) and loading of data into the database occurred concurrently with development of a web application. This approach allowed us to test and validate both the loaded data and the data model structure. The web application was refined iteratively based on ongoing feedback from the development team, working group and various users.

## Database structure

Three primary types of data are handled within the Yukon Permafrost Database: geotechnical data, temperature data, and related reports or documents. Geotechnical and temperature data are stored in sets of tables within an Oracle relational database management system (RDBMS): 13 tables for the geotechnical data (Table 1), and 7 for the temperature data (Table 2). Oracle was selected as the primary database platform for its robust ability to store and serve large volumes of data, as well as to facilitate integration into the Yukon Geological Survey's Integrated Data System (YGSIDS). Reports and documents pertaining to permafrost and geotechnical investigations in Yukon are stored in the Government of Yukon's operational spatial data infrastructure (OPR), which is then linked to the Yukon Permafrost Database through a database connection.

## Geotechnical data

Geotechnical data come from investigations typically performed by geotechnical engineers to obtain information on the physical properties of soil, rock and ice underlying a site for proposed structures or development. Site investigations often include subsurface sampling and laboratory testing of the soil samples retrieved. Test pits, trenching and drilling may also be used to learn about soil conditions at depth. Geotechnical data are relevant to the permafrost database as they contain logs of ground conditions and ice encountered at various depths, providing information about the distribution, and often,

characteristics of ground ice. Additionally, the geotechnical properties of the materials at the site are an important control on the effects of permafrost thaw.

The geotechnical data tables were designed to reflect the workflow traditionally followed during geotechnical investigations: site selection and description; field data collection; instrumentation installation; laboratory testing; and reporting (Table 1). Data are typically initially entered into some type of relational database software (e.g., ESEBASE, gINT, or Holebase) which is used to produce geotechnical logs for inclusion in geotechnical reports. Most geotechnical logging software can export to a variety of tabular formats (e.g., .csv, .xls or .mdb files) which may be imported into the Yukon Permafrost Database.

In the Yukon Permafrost Database there are 13 relational tables (Table 1) with capacity for the range of geotechnical data commonly collected. Tables are connected by one-to-many relationships<sup>1</sup> extending from the primary geotechnical table (PF\_LOCATIONS) through a common field (SITE\_ID).

As each investigation has unique objectives, the amount and type of data collected vary by project. For a given project some fields (i.e., columns) or entire tables may be left blank if they are irrelevant to the investigation. For example, while soil description data are provided for all of the approximately 15 000 boreholes currently loaded into the database, only half have some geotechnical testing data available (e.g., moisture content and/or grain size analyses). About one-fifth of the boreholes entered have permafrost description data. Boreholes lacking permafrost information were intentionally retained in the database because it is equally valuable to know where permafrost was not observed and what the associated ground conditions are.

## Data summary

As of November 2021, the geotechnical component of the database has 15 349 boreholes loaded (Fig. 1). The majority of the geotechnical data were acquired from

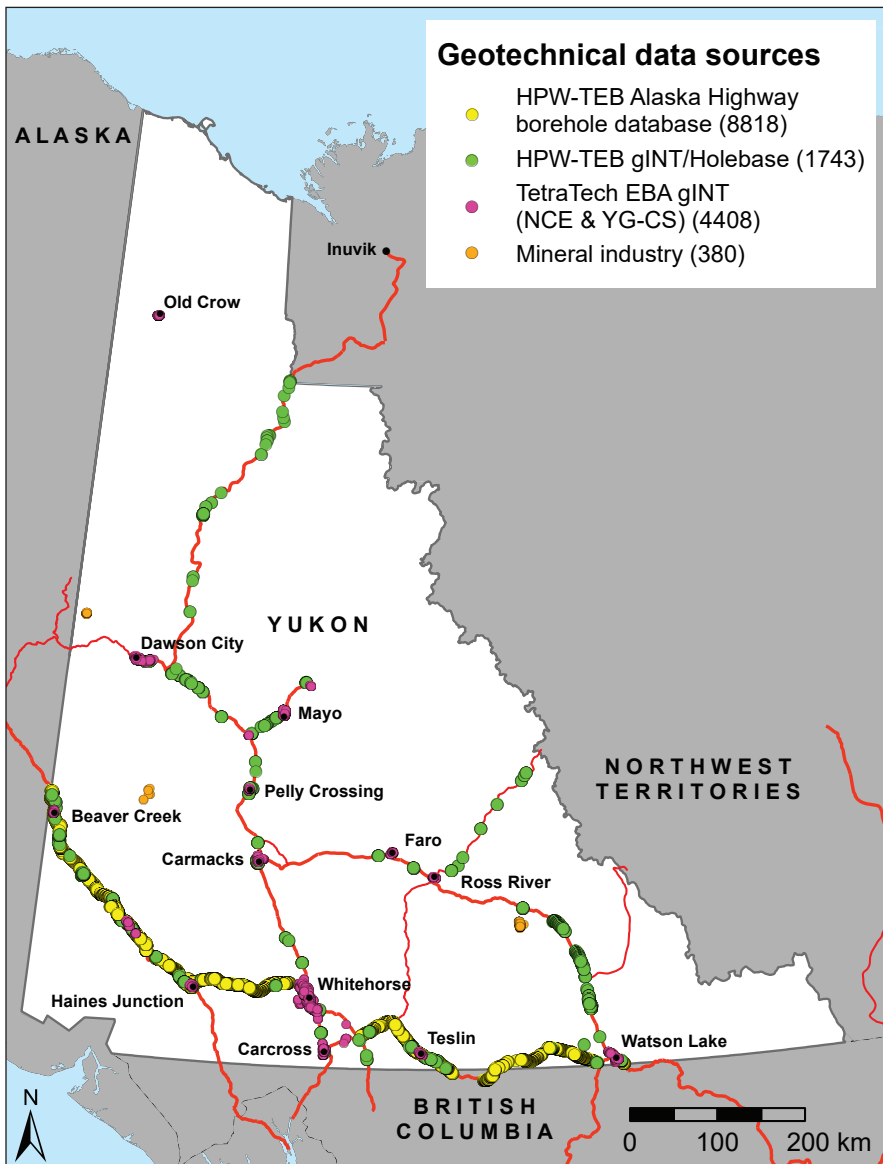
<sup>1</sup> One-to-many relationships allow for one record in a table to be associated with one or more records in another table or multiple tables. For example, each geotechnical site (SITE\_ID) can have many soil stratums or permafrost cryostructure layers associated with that single site within the PF\_SOIL\_DESC or PF\_PERMAFROST\_DESC tables respectively.

**Table 1.** Summary of data tables contained within the geotechnical component of the Yukon Permafrost Database. Tables highlighted in bold text are most commonly used and therefore have the greatest number of records.

Data Collection Workflow Phase	Table Name	General Description	Content
site selection and observation	<b>PF_LOCATIONS</b>	primary geotechnical table, with essential site location and project context information	site ID, location (UTM and/or lat/long), elevation, project name, start/end dates, consultant, client, contractor, equipment, drilling details (core diameter, flush material, borehole plunge/azimuth, hole type and depth), groundwater table
	PF_SURFACE_DESC	information on immediate surroundings of a site	vegetation, organic thickness, topography, drainage, surficial geology, terrain features, snow, slope, aspect, disturbances, ecoregion
data collected during drilling	<b>PF_SOIL_DESC</b>	soil information observed in the field for a single interval or stratum during data collection	depth to the top and bottom of the soil interval/stratum, nature of the lower boundary, soil description, soil classification system (e.g., USCS), USCS code
	<b>PF_PERMAFROST_DESC</b>	frozen ground observations made during field data collection. May include frozen ground not related to permafrost (e.g. seasonal frost)	depth to the top and bottom of the frozen ground interval/stratum, temperature, thaw depth, permafrost cryostructure description, ground ice description, classification system, visual estimate of volumetric ice content
	PF_RECOVERY	information on borehole sample recovery and quality	depth to the top and bottom of the drill run, rock quality designation (i.e., degree of jointing/fracture), core recovery %, fracture frequency
	PF_INSITU	information on in situ testing completed	depth to the top and bottom of the test interval, hydraulic conductivity, shear strength, shear wave velocity, penetration resistance, strength test type, strength, stress
	<b>PF_SAMPLE</b>	information on the soil and material samples collected	depth to the top and bottom of the sample, diameter of core, sample type, USC code for material type, penetration tests
instrumentation installation	PF_INSTALL_DESC	information on instrumentation installed	installation type (e.g., monitoring well, piezometer, inclinometer, ground temperature cable), depth, capped height, type of protector
	PF_BACKFILL	describes backfill used at site	depth to the top and bottom of the backfill, type of backfill (e.g., bentonite, sand, drill cuttings, slough, asphalt, cement, grout, pea gravel, topsoil)
laboratory testing	<b>PF_GEOTECH_TESTING</b>	geotechnical test results completed on soil samples	depth to the top of the sample, bulk and dry density, specific gravity, gravimetric moisture content, Atterberg limits, plasticity index, grain size analyses, organic content, soluble sulphate content, salinity
	PF_ENVIRONMENTAL	environmental test results completed on soil samples	depth to the top and bottom of the test interval, hydrocarbon vapour concentration, lower explosive limit of vapour, soil vapour concentration of volatile organic compounds, electrical conductivity, chloride content, methane content
	PF_PERMAFROST_TESTING	permafrost test results completed on soil samples	depth to the top and bottom of the test interval, thaw weakening susceptibility, thaw strain consolidation, unfrozen water or ice content, creep properties, adfreeze strength, thermal conductivity, latent heat of fusion
reports and logs	<b>PF_GEOTECH_PRODUCTS</b>	metadata for documents that describe a site (e.g., drill logs, reports, journal articles)	document type, URL/web address

\*Tables highlighted in bold text are most commonly used, and therefore have the greatest number of records, as of November 2021.

\*\*Tables highlighted in blue contain no records, as of November 2021, but are available for use in future data submissions.



**Figure 1.** Locations and primary sources of geotechnical data loaded into Yukon Permafrost Database. The number of sites from each source is indicated in brackets. Most of the sites are located within infrastructure corridors and communities, but some are located at more remote mineral properties.

the Alaska Highway Borehole Database (AHBD), Tetra Tech EBA records acquired by Yukon College's Northern Climate ExChange (NCE; now YukonU Research Centre, Yukon University), and Yukon Government (YG) Department of Highways and Public Works (HPW) Transportation Engineering Branch (TEB). Additional data were acquired from private mining industry firms, YG Community Services (YG-CS), and YG Assessment and Abandoned Mines (YG-AAM).

The Alaska Highway Borehole Database was compiled by the YGS between 2005 and 2009 (Lipovsky, 2009). While some records were imported from their ESEBASE

database, the data were largely captured from HPW-TEB's hard copy logbooks from the 1970s to 1990s. The AHBD boreholes were drilled approximately every 100 m down the Alaska Highway centerline and average 5 to 6 m deep. Of the 8818 boreholes in the AHBD dataset, about  $\frac{1}{3}$  of them encountered some form of permafrost.

HPW-TEB also contributed geotechnical data for 1743 boreholes drilled within various highway corridors between 2011 and 2019; these data were exported from their internal gINT and Holebase databases.

In 2011, Yukon College’s Northern Climate ExChange acquired a compilation of Tetra Tech EBA’s gINT geotechnical data that were collected for various public agencies from 1971 to mid-2010 (Tetra Tech EBA, 2011). Tetra Tech EBA also provided gINT geotechnical data collected from approximately 56 additional boreholes drilled for YG Department of Community Services (YG-CS) between 2011 and 2017.

The Geological Survey of Canada (GSC) has also compiled geotechnical data for approximately 600 boreholes within Yukon (primarily located along the Alaska Highway and the north coast), and approximately 14000 boreholes from nearby Mackenzie Valley in Northwest Territories. These data are not included in the Yukon Permafrost Database since they are managed federally. The GSC data may be explored and downloaded from the Permafrost Information Network (PIN) web application (<https://pin.geosciences.ca/>).

### Temperature data

Temperature data, typically in time series format, come from investigations performed by government agencies, geotechnical engineers and consultants,

academics and others to obtain information on the air or ground temperature conditions at a particular location. Ground temperature investigations generally include the installation of temperature sensors at a variety of depths below ground and data loggers which record the temperatures at regular time intervals (e.g., hourly or daily) for varying periods ranging from a few days to several years. Ground temperature investigations also often involve the installation or monitoring of above-ground weather stations which provide data required to understand the relationship between the ground thermal regime and local climate. For this reason, the temperature component of the Database was designed to include air temperature and other climate data (e.g., surface description, permafrost description, ground temperature, thaw depth, air humidity, air temperature, soil moisture, water level, wind speed and wind direction).

In the Database, temperature data are stored in seven tables (Table 2) within an Oracle relational database management system (RDBMS). As each investigation has unique objectives, the level and type of data collected vary by project.

**Table 2.** Summary of data tables contained within the temperature component of the Yukon Permafrost Database.

Table Name	General Description	Content
<b>PFT_LOCATIONS</b>	site location and basic site metadata	site name, location (latitude/longitude), location accuracy, elevation, elevation accuracy, local relief, permafrost presence, comments
<b>PFT_OBSERVATIONS</b>	primary table in the temperature component of the database, containing all observations	depth to the top and bottom of the observation, start and end time of observation, observation value and type (e.g., air humidity, air temperature, ground temperature, permafrost characterization, soil moisture, surface description, surface temperature, thaw depth, water level, wind direction, wind speed)
<b>PFT_WHO</b>	information on data ownership	contact name, and institution or affiliation
<b>PFT_METHOD</b>	information on instrumentation installed at a site	sensor and data logger manufacturer and model; measurement precision, accuracy and units; radiation shield description
PFT_DISTURBANCE	description of disturbances that have occurred at or near a site	disturbance type (e.g., road, trail, excavation, urban, building, fire, stream, lake, thermokarst), proximity to disturbance, estimated date of disturbance, comments
PFT_DOIS	metadata for documents that describe a site	DOI (Digital Object Identifier) of document, and associated notes (e.g., document type)
PFT_OBSERVATION_DOI	intermediate table used to link records between tables	ID fields referring to records in the PFT_OBSERVATIONS and PFT_DOIS tables

\*\*Tables highlighted in blue contain no records, as of November 2021, but are available for use in future data submissions.

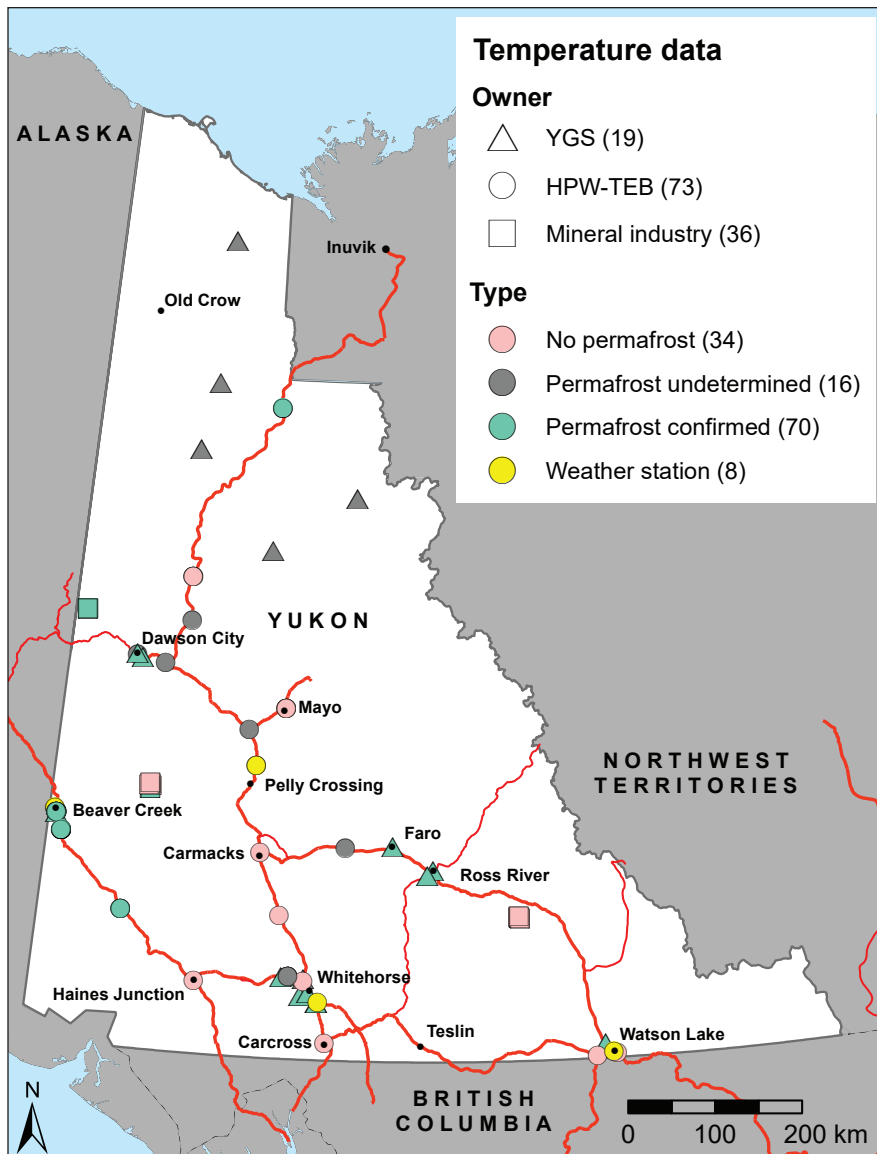
## Data summary

As of November 2021, 128 sites have been loaded into the temperature component of the Yukon Permafrost Database. Temperature data were provided by the YG Department of Highways and Public Works Transportation and Engineering Branch (HPW-TEB), Yukon Geological Survey, Assessment and Abandoned Mines, and the mineral industry (Fig. 2; Table 3).

Permafrost is confirmed at 70 sites and is not present at 34 sites (Fig. 2). Permafrost presence is undetermined at 16 sites for various reasons: boreholes are too shallow (i.e., <2 m depth); ground temperatures are so close to 0°C that perennially frozen ground can't be verified

within the precision limitations of the instruments; the record of measurement is too short; or there are gaps in the data.

HPW-TEB has 73 temperature monitoring sites across the territory (Table 3), largely operated within their Intelligent Transportation System (ITS) network. Eight of these sites are weather stations. Many of the HPW-TEB sites are clustered near specific areas of interest. For example, there are 27 sites at Beaver Creek and the nearby Shakwak test section (km 1865 Alaska Highway); 11 sites at the Dry Creek thermosiphon installation (km 1841 Alaska Highway); 9 sites along the Dempster Highway (km 0, 65, 124 and 421); 4



**Figure 2.** Locations and primary sources of temperature data loaded into Yukon Permafrost Database. The number of sites is indicated in brackets.

**Table 3.** Key attributes of the 128 temperature monitoring sites included in the Yukon Permafrost Database, including period of data collection, borehole depth, and presence of permafrost.

Source	Area	Location**	Number of sites	BH's in permafrost	BH Bottom Depth (m)	Data collection period
HPW-TEB	Beaver Creek and Shakwak test section	AH km 1865, 1870	27*	25	8-16	1997/2008-2019
	Dry Creek	AH km 1841	11*	10	12.5-15	2019-2020
	Dempster Highway	DH km 0, 65, 124, 421	9	1	2-20	2007-2021
	Burwash Creek	AH km 1715	4*	3	10	2015-2021
	Takhini Valley	AH km 1457	4*	1	10	2014-2021
	Mayo Airstrip		4*	?	10	2014-2021
	Watson Lake	AH km 1002, 980, 976	3*	0	2-4	2008-2020
	Haines Junction bridge	HR km 245.5	1	0	4	2008-2019
	Carcross	SK km 106 (at Tagish Rd junction)	1	0	4.2	2009-2019
	Braeburn	NK km 281	1	0	4.1	2005-2019
	Carmacks	NK km 359	1	0	2	2008-2019
	Pelly Crossing	NK km 488	2*	?	2	2017-2021
	Stewart Crossing	NK km 534	1	?	4	2007-2019
	Dawson City at Dome Rd	NK km 713	1	?	2	2008-2019
	Alaska Highway at North Klondike Highway junction	AH km 1437	1	0	4.1	2013-2020
	Alaska Highway at South Klondike Highway junction	AH km 1404	1*	0	4.0	2014-2018
Drury Creek	RC km 468	1	?	2	2014-2020	
YGS	North Yukon, US Array sites		5	?	0.5-1.5	2017-2019 & 2019-2021
	South Canol Rd (Tintina well)	SC km 216	1	1	58.43	2018 (Apr. 20 - Sept. 18)
	Beaver Creek test section	AH km 1865	1	1	5	2007-2021
	Dawson City	School and dump	2	2	2-3.4	2007-2021
	Faro		1	1	4	2007-2019
	Ross River	School	1	1	13	2007-2018
	Watson Lake	RC km 16.5	1	1	2.8	2009-2015
	Greater Whitehorse:					
	Cowley Creek		2	2	5	2007-2020
	Hamilton Blvd		1	1	2.2	2019-2021
	Fish Lake		1	1	3	2020-2021
	Hidden Valley		1	?	18.8	2019-2020
	Takhini thaw slump	AH km 1456.5	1	1	20	2020-2021
	Takhini Valley	AH km 1465	1	1	18.8	2019-2021

Table 3 continued.

Source	Area	Location**	Number of sites	BH's in permafrost	BH Bottom Depth (m)	Data collection period
AAM	Clinton Ck Mine		11	8	14-70	2018-2019
	Casino property		12	6	27-76	1994 & 2010-2019
	Kudz Ze Kayah property		13	0	29-70	2016-2017

\* includes 1 weather station

? indicates unknown

\*\*AH = Alaska Highway, DH = Dempster Highway, HR = Haines Road, SK = South Klondike Highway, NK = North Klondike Highway, SC = South Canol Road, RC = Robert Campbell Highway

sites at each of the Mayo airstrip, Takhini Valley (km 1457 Alaska Highway) and Burwash Creek area (km 1715 Alaska Highway); and 3 sites near Watson Lake (km 976, 980 and 1002 Alaska Highway). Haines Junction, Carcross, Braeburn, Carmacks, Pelly Crossing, Dawson City, Alaska Highway at North Klondike Highway junction, and Drury Creek each have one site nearby.

Data from 19 Yukon Geological Survey sites are included in the database (Table 3). Five shallow (0.5–1.5 m depth) holes were instrumented from 2017 to 2019 in the remote Richardson and Ogilvie Mountains of north Yukon as part of the US Array campaign (<http://www.usarray.org/Alaska>). Ground temperature data down to 58 m depth are available for the Tintina geothermal well (Fraser et al., 2019), located at km 216 of the South Canol Road. Long-term ground temperature data dating back to 2007 are available for six community permafrost monitoring sites located in Beaver Creek, Dawson, Faro, Ross River and Watson Lake (Lipovsky and Yoshikawa, 2009 and Lipovsky, 2014). The database also includes ground temperatures from seven permafrost monitoring sites that YGS maintains in the greater Whitehorse area (Roy et al., 2021).

Data from 36 sites at three mineral properties were submitted (Table 3): 25 from private industry; and 11 sites from YG Assessment and Abandoned Mines (YG-AAM) for the Clinton Creek Mine. Data from the mineral industry are particularly valuable as many were collected from very deep boreholes that extend

up to 76 m. The data also provide insight into permafrost conditions at elevations higher (i.e., >1100 m) than most other sites. For example, very deep permafrost is recorded in the Dip Creek valley near the Casino property, extending from approximately 4 m depth to at least 50 m depth (CAS\_DH12-01). In undisturbed ground adjacent to Clinton Creek mine, two boreholes (BH18-08 and BH18-15) record permafrost down to at least 14 m depth, with active layers of 4 and 5 m, respectively.

## Reports

The reports component of the Yukon Permafrost Database comprises a spatial catalogue of reports, maps, posters, journal articles and academic theses pertaining to permafrost and geotechnical investigations in Yukon. Each document was georeferenced (“footprinted”) in ESRI ArcGIS to capture the spatial extent of the work as a point, line (e.g., a section of highway), or polygon feature class as appropriate. Attributes collected for each feature include the title, author, year published, document type, general location of work and download URL.

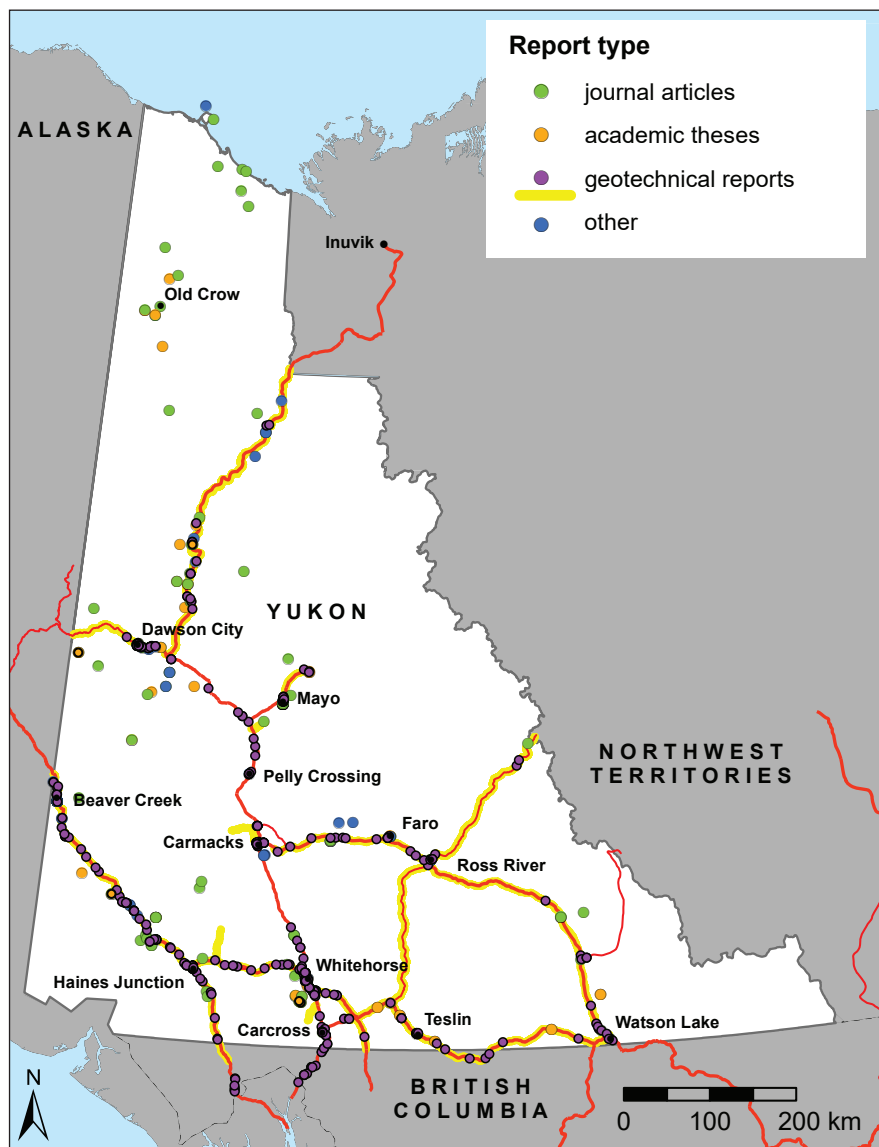
Permafrost-related documents come from many sources, only some of which are openly accessible. Within the catalogue links are provided, where available, to download publicly available documents from an FTP site, while proprietary URLs or DOI links are provided for documents that do not have open access, such as selected journal articles.

Overall, this component of the database provides a comprehensive summary of the permafrost literature available in Yukon. It offers an accessible and convenient method of determining what permafrost-related work has been done in the territory and where, and will facilitate gathering relevant literature for specific areas of interest. The collection will be updated annually to incorporate new permafrost-related literature directly pertaining to Yukon.

As of November 2021, the documents catalogued in the reports component of the Yukon Permafrost Database include 167 journal articles, 56 academic theses, 121 geotechnical reports, and 111 other documents such as internal reports, maps, and conference posters. The locations of these documents are shown in Figure 3.

## Web application

The database is accessible through a web application at <https://yukon.ca/en/yukon-permafrost>. Locations of geotechnical investigation and ground temperature monitoring sites are presented in interactive web map platforms. Borehole logs and sample analyses for individual geotechnical sites may be viewed in tabular format, while data for individual ground temperature monitoring sites may be visualized in interactive time-series graphs, ground temperature envelopes and tables. Other modules of the web application allow users to explore Yukon permafrost-related reports and publications, and previously released permafrost products such as a permafrost probability model



**Figure 3.** Locations of work described within reports loaded into the Yukon Permafrost Database. Yellow highlighting indicates road segments described in geotechnical reports.

(Bonnaventure et al., 2012) and a periglacial landform atlas (Huscroft et al., 2021). All database tables are available for download in CSV format, while site locations may be downloaded in a variety of spatial data formats (ESRI feature geodatabase, ESRI shapefile and Google Earth KMZ). Standardized templates for data submissions are also available for download.

## Quality control and data processing

Some data cleaning and processing were required to convert data to a format consistent with the data model and to facilitate loading into the Database. Quality assurance and quality control (QA/QC) measures adopted include the automation of data processing where possible using R scripts, manually verifying and inspecting data at regular intervals, and documentation of processing steps.

Due to the range of data sources and formats, geotechnical data were processed using a combination of manual and automated methods. This involved some restructuring of the raw data tables, and conversion of location coordinates and date/time formats. No modifications were made to original soil and permafrost descriptions, terminology or testing values.

Temperature data were cleaned to a minimal extent using automated processing, largely to optimize the web application data visualization tools. Null values and major outliers were removed, and temporal data were converted to a standardized time and date format. Raw unprocessed data and R scripts used for processing may be provided by YGS upon request.

## Data limitations

The data presented in the Database are an amalgamation of multiple data sources and decades of geotechnical investigations in Yukon. While the database was designed to allow for all data that may reasonably be collected at a site, this approach also presented some challenges in assimilating the diversity of geotechnical logging styles encountered, and in some cases results in data that are difficult to compare with other sources. Geotechnical field logs and laboratory testing on

discrete samples inherently impart some degree of generalization for any given site. The data were collected based on specific objectives of host organizations and the geotechnical standards at the time, which may differ from those at present, and with variable equipment, procedures, standards and personnel. The precision and accuracy of site coordinates may also vary as positioning systems have varied over time. Site conditions may have changed since the collection of historical data, such as slope stability investigations, foundation evaluations for future infrastructure, or granular resource investigations where material may have since been excavated. Site conditions at ground temperature investigation sites may also have changed since data collection, for example through thermal or mechanical erosion or landscape change.

A substantial proportion of the geotechnical and temperature data included in the Database do not include any permafrost information. These data were retained because it may be valuable to know where permafrost was not observed and the associated ground conditions. However, the absence of permafrost descriptions in geotechnical logs does not necessarily mean that permafrost is not present at that location. In some cases, it can be very difficult to tell whether permafrost is present or not at the time of drilling (e.g., in ice-poor ground, or in ground that is marginally frozen and possibly thawed during the drilling process), so it may not have been noted at the time of recording, or it may be present at greater depth.

The contents of the Database are made available “as is” and without warranty of any kind. Despite our best quality control efforts, errors, gaps or omissions may still exist. Please contact [ygs-surficial@yukon.ca](mailto:ygs-surficial@yukon.ca) to report any issues encountered so they may be corrected.

The Database serves as a reference to aid in understanding areas of interest and planning further data collection programs. Professional judgement and interpretation should be used where possible to assess the value and validity of these data for a particular purpose.

## Data ownership and use policy

Geotechnical and temperature data ownership resides with the original data sources summarized above (Figs. 1 and 2) and is also indicated in the metadata tabs of the web application. These data providers have agreed to make data publicly available within the Database for third party use with the provision that any publications which reference these data cite the Database as the source. Any enquiries about the data should be directed towards YGS and not the original owners.

## Data submissions

The Database will be maintained and updated regularly and we strongly encourage ongoing data contributions from any source. We would particularly welcome submissions from the mineral industry to enhance our understanding of deep permafrost in the territory, outside public infrastructure corridors.

Templates have been developed to optimize the process of importing new geotechnical and temperature data (available from <https://service.yukon.ca/permafrost/Downloads.html>), ensuring they are provided in a consistent manner compatible with the Database. We are working to incorporate these standardized templates in all future geotechnical contracts tendered by the Government of Yukon.

## Summary

The Yukon Permafrost Database is a compilation of geotechnical and ground temperature data and related literature from a variety of sources including government and industry. Data may be explored interactively and downloaded in a variety of formats from a publicly accessible web application (<https://yukon.ca/en/yukon-permafrost>).

The Database is a valuable resource for a variety of stakeholders, including land use planners, regulators, First Nations governments, municipal governments, Government of Yukon branches, academic researchers, geotechnical consultants and contractors. The Database may also support a variety of applications,

including permafrost distribution and thermal regime evaluations, thaw-related hazard and risk assessments, climate change modeling, development of community adaptation plans, infrastructure planning and maintenance, and environmental assessments.

The Database is an evolving product that is updated regularly as new data become available. We welcome submissions from any contributors in order to maximize our collective knowledge of permafrost in Yukon.

## Acknowledgements

Brett Elliot, Kisa Elmer and Moya Painter have been integral to the development and maintenance of the Yukon Permafrost Database, which would never have become a reality without their substantial efforts. We are extremely grateful for all the feedback shared by the Yukon permafrost database working group, and for helpful permafrost data management discussions and support offered by Nick Brown (NSERC PermafrostNet), Sharon Smith (Geological Survey of Canada), and Ashley Rudy (Northwest Territories Geological Survey). We are also very appreciative of Niels Weiss and Karen MacFarlane for their thorough reviewing and editing efforts. Finally, many thanks to all our data contributors, particularly Western Copper and Gold Corporation and BMC Minerals.

## References

- Carleton University, 2021. Cryospheric Observations Longterm Database and Storage System. <https://carleton.ca/permafrost/?p=644>, [accessed 26 August 2021].
- Bonnaventure, P.P., Lewkowicz, A.G., Kremer, M. and Sawada, M.C., 2012. A permafrost probability model for the southern Yukon and northern British Columbia, Canada. *Permafrost and Periglacial Processes*, vol. 23, p. 52–68, <https://doi.org/10.1002/ppp.1733>.
- Fraser, T., Colpron, M. and Relf, C., 2019. Evaluating geothermal potential in Yukon through temperature gradient drilling. In: *Yukon Exploration and Geology 2018*, K.E. MacFarlane (ed.), Yukon Geological Survey, p. 75–90.

- Government of Yukon, 2020. Our Clean Future: A Yukon Strategy for Climate Change, Energy and a Green Economy, 72 p.
- Huscroft, C.A., Elliot, B.T. and Lipovsky, P.S., 2021. Yukon Landform Atlas: permafrost and other periglacial landforms. Yukon Geological Survey storymap, <https://yukon.maps.arcgis.com/apps/MapSeries/index.html?appid=8deacc9f1da84690aebce3dfd11c2958>, [accessed 27 September 2021].
- Lipovsky, P.L. 2009. Interim release of Alaska Highway Borehole Database. Yukon Geological Survey, interim report, March 24, 2009, [http://ygsftp.gov.yk.ca/data/surficial\\_geology/Alaska\\_Highway\\_borehole\\_database\\_interim\\_release\\_March2009/Alaska\\_Highway\\_borehole\\_database\\_interim\\_release\\_March2009.zip](http://ygsftp.gov.yk.ca/data/surficial_geology/Alaska_Highway_borehole_database_interim_release_March2009/Alaska_Highway_borehole_database_interim_release_March2009.zip), [accessed 16 September 2021].
- Lipovsky, P.S., 2014. Summary of Yukon Geological Survey permafrost monitoring network results, 2008–2013. In: Yukon Exploration and Geology 2014, K.E. MacFarlane, M.G. Nordling and P.J. Sack (eds.), Yukon Geological Survey, p. 113–122.
- Lipovsky, P.S. and Yoshikawa, K., 2009. Initial results from the first year of the Permafrost Outreach Program, Yukon, Canada. In: Yukon Exploration and Geology 2008, L.H. Weston, L.R. Blackburn and L.L. Lewis (eds.), Yukon Geological Survey, p. 161–172.
- NSERC PermafrostNet, 2021. PermafrostNet website, <https://www.permafrostnet.ca/>, [accessed 12 July 2021].
- Northwest Territories Geological Survey, 2021. Building a Northwest Territories Permafrost Database, <https://www.nwtgeoscience.ca/services/building-northwest-territories-permafrost-database>, [accessed 23 November 2021]
- O'Neill, H.B., Duchesne, C., Jardine, S. and Smith, S.L. 2018. Permafrost Information Network (PIN) Geotechnical Borehole Database (beta), summary and database field descriptions. Geological Survey of Canada, 9 p.
- Permafrost Information Network, 2021. The permafrost information network, <https://pin.geosciences.ca/>, [accessed 12 July 2021].
- Roy, L.-P., Lipovsky, P.S., Calmels, F., Laurent, C., Humphries, J. and Vogt, N., 2021. Greater Whitehorse area permafrost characterization. Yukon Geological Survey, Miscellaneous Report MR-22, 185 p., including appendices.
- Schaefer, K., Elshorbany, Y., Jafarov, E., Schuster, P.F., Striegl, R.G., Wickland, K.P. and Sunderland, E.M. 2020. Potential impacts of mercury released from thawing permafrost. Nature Communications, vol. 11, 6 p., <https://doi.org/10.1038/s41467-020-18398-5>
- Schuur, E.A.G., McGuire, A.D., Schädel, C., Grosse, G., Harden, J.W., Hayes, D.J., Hugelius, G., Koven, C.D., Kuhry, P., Lawrence, D. M., Natali, S. M., Olefeldt, D., Romanovsky, V.E., Schaefer, K., Turetsky, M.R., Treat, C.C. and Vonk, J.E. 2015. Climate change and the permafrost carbon feedback. Nature, vol. 520, p. 171–179, <https://doi.org/10.1038/nature14338>.
- Smith, S.L., Burgess, M.M., Chartrand, J. and Lawrence, D.E., 2005. Digital borehole geotechnical database for the Mackenzie Valley/Delta region. Geological Survey of Canada, Open File 4924, 25 p., <https://doi.org/10.4095/220383>.
- Tetra Tech EBA, 2011. Geotechnical testhole database for hazards mapping – Yukon communities. EBA File W14101378, January 19, 2011.

