



Natural Resources
Canada

Ressources naturelles
Canada

**GEOLOGICAL SURVEY OF CANADA
OPEN FILE 9298e**

**Electrical resistivity tomography surveys for characterizing
permafrost conditions following wildfire, southern Northwest
Territories, 2015–2018**

J.E. Holloway, Y. Wang, A.G. Lewkowicz, and S.A. Wolfe

2025

Canada 

GEOLOGICAL SURVEY OF CANADA
OPEN FILE 9298e

Electrical resistivity tomography surveys for characterizing permafrost conditions following wildfire, southern Northwest Territories, 2015–2018

J.E. Holloway¹, Y. Wang², A.G. Lewkowicz¹, and S.A. Wolfe²

¹ Department of Geography, Environment and Geomatics, University of Ottawa, 60 University, Ottawa, Ontario K1N 6N5

² Natural Resources Canada, Geological Survey of Canada, 601 Booth Street, Ottawa, Ontario K1A 0E8

2025

© His Majesty the King in Right of Canada, as represented by the Minister of Natural Resources, 2025

Information contained in this publication or product may be reproduced, in part or in whole, and by any means, for personal or public non-commercial purposes, without charge or further permission, unless otherwise specified.

You are asked to:

- exercise due diligence in ensuring the accuracy of the materials reproduced;
- indicate the complete title of the materials reproduced, and the name of the author organization; and
- indicate that the reproduction is a copy of an official work that is published by Natural Resources Canada (NRCan) and that the reproduction has not been produced in affiliation with, or with the endorsement of, NRCan.

Commercial reproduction and distribution is prohibited except with written permission from NRCan. For more information, contact NRCan at copyright-droitdauteur@nrcan-rncan.gc.ca.

This publication is available for free download through the NRCan Open Science and Technology Repository (<https://ostrnrcan-dostrncan.canada.ca/>).

Recommended citation

Holloway J.E., Wang, Y., Lewkowicz, A.G., and Wolfe, S.A., 2025. Electrical resistivity tomography surveys for characterizing permafrost conditions following wildfire, southern Northwest Territories, 2015–2018; Geological Survey of Canada, Open File 9298e, 1 .zip file. <https://doi.org/10.4095/p2apct5ftt>

Publications in this series have not been edited; they are released as submitted by the author.

ISSN 2816-7155
ISBN 978-0-660-78564-6
Catalogue No. M183-2/9298E-PDF
<https://doi.org/10.4095/p2apct5ftt>

Introduction

This Open File contains data from 129 electrical resistivity tomography (ERT) surveys conducted for the characterization of permafrost and ground conditions at 19 study sites in the southern Northwest Territories from 2015 to 2018. Of the 19 study sites, 16 were disturbed by forest fire in 2014 or 2015 (burned - B), while three sites remained undisturbed/unburned (unburned - UB). A description of the study sites and methodology are presented in the main document, and the individual survey results are provided as .dat files. This Open File supports ongoing research by the Geological Survey of Canada on post-fire permafrost dynamics in the southern Northwest Territories and accompanies Open File 9299, entitled “Field observations of climate, soil, and ecological conditions within the first five years following wildfire, southern Northwest Territories”. Additional details are available in Holloway (2020).

This Open File contains a .zip with survey results (.dat files) organized into individual folders for each study site, as well as a table (.csv) that summarizes all of the surveys that were conducted.

Study area and sites

The following description of the study area and study sites is also provided in Open File 9299, entitled “Field observations of climate, soil, and ecological conditions within the first five years following wildfire, southern Northwest Territories”.

The monitoring sites were selected by applying a stratified random sampling scheme within seven areas burned by wildfire in 2014 or 2015 along Highways 1 and 3, mainly between Kakisa and Behchoko (Figure 1). The strata represented a range of vegetation types, fire severities, and fire histories. Further site selection occurred in the field, based on the presence of a frost table and other conditions indicative of permafrost. The sites were established in 2015 (n=16), 2016 (n=2), and 2017 (n=1) and were revisited annually from 2015 to 2019, with some exceptions due to logistical constraints (Table 1). The study sites are aligned along a transect that runs southwest to northeast, perpendicular to regional mean annual air temperature isotherms, the boundary between the sporadic and extensive discontinuous permafrost zones (Heginbottom et al. 1995), and the boundary between the Taiga Plains and Taiga Shield ecozones.

The regional climate is subarctic and continental, with a mean annual air temperature (MAAT) of -4.0°C at Yellowknife (62.5°N) and -2.2°C at Hay River (60.1°N) (1991-2020 climate normal) (Environment and Climate Change Canada 2025). Mean total annual precipitation is 294 mm at Yellowknife and 320 mm at Hay River, with snow fractions of 0.39 and 0.34, respectively (1991-2020 climate normal) (Environment and Climate Change Canada 2025).

Fifteen sites are in the Taiga Plains ecozone, while four sites near Yellowknife are in the Taiga Shield ecozone. The Taiga Plains consist of a gently rolling sedimentary bedrock plain overlain by till and glaciolacustrine deposits. The vegetation is predominantly black spruce (*Picea mariana*) in the lowlands and mixed forest in the uplands, with understories commonly composed of mosses, lichens, sedges, and Labrador tea (*Rhododendron groenlandicum*). The Taiga Shield comprises undulating exposed igneous and metamorphic bedrock, with low-lying wetlands underlain by till and glaciolacustrine deposits. Jack pine (*Pinus banksiana*), black spruce, and paper birch (*Betula papyrifera*) occur in thin soils at upland sites, while black spruce dominates lowlands. Wetlands constitute 40% of the area, with peat thicknesses of 2 to 6 m (Gibson et al. 2018).

The southern part of the transect falls within the sporadic discontinuous permafrost zone, where permafrost thicknesses are less than 30 m and mean annual ground temperatures are greater than -1°C (Smith et al. 2008, 2015). The northern part of the transect is in the extensive discontinuous permafrost zone, where permafrost is less than 50 m thick and has mean annual ground temperatures above -2°C (Wolfe et al. 2015, Morse et al. 2016).

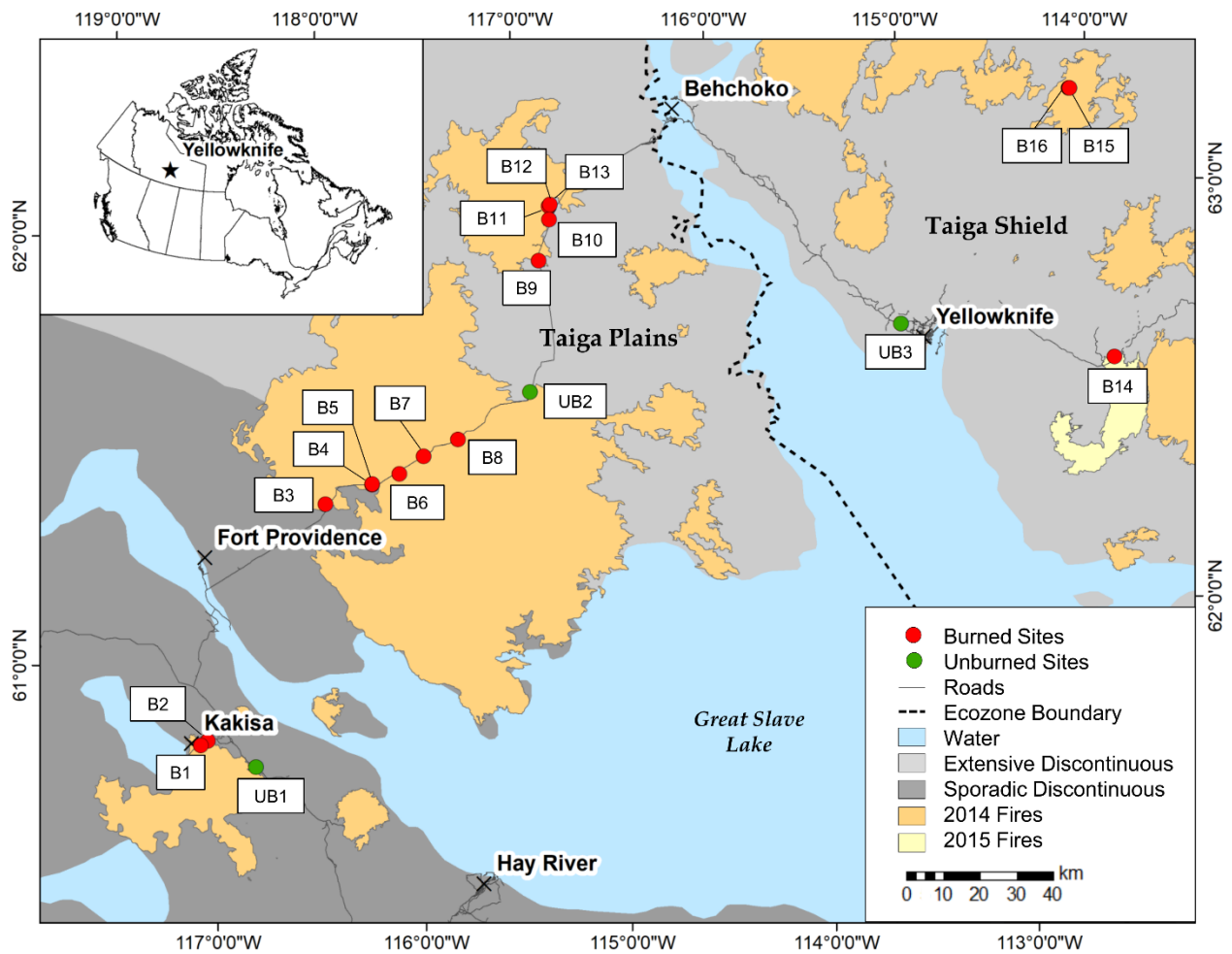


Figure 1. Map of study area in the southern Northwest Territories, Canada, including burned (n=16) and unburned (n=3) sites, major roads, 2014 and 2015 fire boundaries (Northwest Territories Centre for Geomatics 2015), ecozones (Government of Northwest Territories 2008), and permafrost distribution zones (Heginbottom et al. 1995). Inset map shows the location of Yellowknife within Canada.

Table 1. Study site names, coordinates, descriptions, ecozones, dates visited, and estimated permafrost thicknesses.

Site name / ID	Latitude, Longitude (°)	Description (e.g., soil moisture, landform, vegetation, local topography)	Ecozone	Dates visited (YYYY-MM-DD)	Permafrost thickness (m)
B1 (SS33-9a)	60.941, -117.366	Mesic-subhygric. Peat plateau, lots of thermokarst. No slope.	South Taiga Plains	2015-06-16 2015-08-16 2016-05-17 2016-09-01 2017-08-29 2018-09-03	15-20
B2 (SS33-6c)	60.958, -117.339	Subhygric. Spruce forest, lots of mounding. No slope.	South Taiga Plains	2015-06-04 2015-08-14 2016-09-06	None
B3 (ZF20-34b)	61.608, -117.154	Mesic-subxeric. Gradient from pine to spruce to bog. No slope.	Central Taiga Plains	2015-06-02 2015-08-15	None
B4 (ZF20-6b-1)	61.689, -116.952	Mesic-subxeric. Severely burned, all trees down. No slope.	Central Taiga Plains	2015-06-08 2015-08-15 2016-05-13 2016-09-07 2017-09-01 2018-09-07	10 (patch)
B5 (ZF20-6b-LK)	61.692, -116.953	Mesic-subhygric. Wet spruce forest near pond; one end has thick peat plateau and the other is a very wet marsh.	Central Taiga Plains	2015-06-11 2015-08-18 2016-05-13 2016-09-05 2017-09-02 2018-09-06	15
B6 (ZF20-12b)	61.736, -116.834	Mesic. Gradient from pine to black spruce to bog. No slope.	Central Taiga Plains	2015-06-14 2015-08-13 2016-05-15 2016-09-03 2017-08-31 2018-09-08	5 (small patch)
B7 (ZF20-9c)	61.796, -116.740	Mesic-subhygric. Spruce forest with lots of mounds, and small section of unburned. No slope.	Central Taiga Plains	2015-06-10 2015-08-19 2016-05-14 2016-09-04 2017-09-01 2018-09-05	5-10
B8 (ZF20-4a)	61.863, -116.597	Mesic-subxeric. Gradient of burn severity from unburned to severely burned. No slope.	Central Taiga Plains	2015-06-02 2015-08-17 2016-05-14 2016-09-02 2017-08-30 2018-09-09	10-20
B9 (ZF46-18b)	62.345, -116.482	Mesic-subhygric. Pine with small area of black spruce. No slope.	North Taiga Plains	2015-06-09 2015-08-12 2016-05-11 2016-09-14 2017-09-05 2018-09-12	>5
B10 (ZF46-35c)	62.450, -116.496	Mesic. Pine and dwarf black spruce patch. No slope.	North Taiga Plains	2015-06-09 2015-08-20 2016-05-16 2016-09-13 2017-09-05 2018-09-12	>5
B11 (ZF46-1b-1)	62.480, -116.518	Mesic-subhygric. Small valley, pine on top of hill, spruce in valley bottom (wet/boggy). Hill slope is 30° and valley bottom (60 m) is flat. Sandy.	North Taiga Plains	2015-06-06 2015-08-20 2016-05-15 2017-09-06 2018-09-11	5 (small patch)
B12 (ZF46-1b-2)	62.481, -116.520	Mesic-subhygric. Small valley, pine on top of hill, spruce in valley bottom (wet/boggy). Transect goes	North Taiga Plains	2015-06-06 2015-08-20 2016-05-20 2016-09-15	5-10

		through burned and unburned area. Hill slope is 30° and valley bottom (60m) is flat. Sandy.		2017-09-06 2018-09-11	
B13 (ZF46-1c)	62.485, -116.518	Mesic. Spruce stand. Sandy. No slope.	North Taiga Plains	2015-06-10 2015-08-19 2016-06-03 2016-09-15 2017-09-05 2018-09-10	5-10
B14 (TIB-1)	62.522, -113.382	Burned peatland with ice wedges.	Taiga Shield	2016-06-16 2016-09-12 2017-09-07 2018-09-14	>24
B15 (LL-PEAT)	63.133, -114.004	Peatland in valley next to lithalsas.	Taiga Shield	2015-06-18 2015-08-30 2016-09-10 2018-08-25	>24 m
B16 (LL-LITH2)	63.132, -114.006	Lithalsa topped with spruce and birch trees.	Taiga Shield	2015-06-18 2015-08-30 2016-09-11 2018-08-25	>24 m
UB1 (KAK-UB)	60.935, -117.072	Mesic-subhygric. Unburned forest. No slope.	South Taiga Plains	2017-08-23 2018-09-04	5 m
UB2 (HWY3-UB-1A)	62.029, -116.314	Mesic-subhygric. Unburned forest. No slope.	Central Taiga Plains	2016-05-18 2016-09-09 2017-09-03 2018-09-10	>24 m
UB3 (UB-1)	62.458, -114.532	Unburned peat plateau.	Taiga Shield	2015-06-07 2015-08-11 2016-05-31 2016-09-16 2017-09-07 2018-09-13	>24 m

Electrical resistivity tomography

Electrical resistivity tomography (ERT) is a geophysical method that is becoming a standard technique in the study and characterization of permafrost (Herring et al. 2023). ERT is useful for understanding permafrost conditions because frozen ground, particularly if it is ice-rich, is several orders of magnitude more resistive than unfrozen ground containing porewater.

ERT surveys are conducted by inserting metal electrodes into the ground along a survey line (Figure 2). The electrodes are connected to a power source through a series of cables, and then a DC electrical current is sent through the cables to the electrodes. The resulting voltage difference measured through other electrodes indicates the resistivity of the ground between these electrodes to the current. In a single survey, many measurements are collected using different combinations of electrodes, allowing for 2-dimensional visualization of resistivity patterns to a certain depth of investigation. Generally, the longer the surveys, the greater the depth of investigation. During the measurements, the instrument records apparent resistivities, which are indirect indicators of the ground resistivity.

ERT surveys are often supplemented by additional field information to provide context and to support the interpretation of permafrost presence and distribution. Thaw depths, measured using a frost probe, can help to indicate the presence of frozen ground and identify local thresholds for frozen versus unfrozen ground (Mackay 1977, Way et al. 2018, 2021). Topographical information along survey lines can also provide context, with elevated areas potentially indicating permafrost landforms underlain by ground ice and lower spots indicating areas that may have subsided due to thermokarst development.



Figure 2. Electrodes and cables used in an electrical resistivity tomography survey conducted in August 2016.

At these study sites (Table 2), surveys were conducted using the ABEM Terrameter LS. Surveys were 40, 80, or 160 m in length, reaching depths of investigation of approximately 6, 12, and 24 m, respectively. Minimum electrode spacings were set to 0.5, 1, or 2 m for the 40, 80, and 160 m-long surveys, respectively. The shorter surveys with smaller electrode spacings provide higher resolution tomograms of the active layer and uppermost permafrost, whereas the longer surveys with larger electrode spacings provide greater depths of investigation that can indicate the base of permafrost. Surveys were collected in a Wenner array, for its stability in heterogeneous regions and clear delineation of horizontal structures, such as the base of the active layer and the top and bottom of the permafrost (Hauck et al. 2004, Fortier et al. 2008, Herring et al. 2023). Topographic information was collected along these survey lines using a handheld Abney level in 2015 or a ZipLevel Pro-2000 altimeter in 2016, 2017, and 2018. The topography was calculated relative to a starting elevation that was measured using the Trimble R7 differential GPS. The topographic data is appended to each of the .dat files.

Table 2. Summary of ERT surveys conducted at 19 study sites in the southern Northern Territories from 2015 to 2018 following wildfires in 2014 and 2015.

Site	Latitude (°)	Longitude (°)	Number of surveys	Dates visited (YYYY-MM-DD)	Survey length(s) (m)
B1	60.94252	-117.36760	10	2015-06-16 2015-08-16 2016-05-17 2016-09-01 2017-08-29 2018-09-03	40 160
B2	60.95821	-117.33925	4	2015-06-04 2015-08-14 2016-09-06	40 160
B3	61.60719	-117.15216	2	2015-06-02 2015-08-15	160
B4	61.68981	-116.95195	10	2015-06-08 2015-08-15 2016-05-13 2016-09-07 2017-09-01 2018-09-07	40 160
B5	61.69166	-116.95312	10	2015-06-11 2015-08-18 2016-05-13 2016-09-05 2017-09-02 2018-09-06	40 160
B6	61.73540	-116.83377	10	2015-06-14 2015-08-13 2016-05-15 2016-09-03 2017-08-31 2018-09-08	40 160
B7	61.79598	-116.74158	6	2015-06-10 2015-08-19 2016-05-14 2016-09-04 2017-09-01 2018-09-05	160
B8	61.86187	-116.59834	10	2015-06-02 2015-08-17 2016-05-14 2016-09-02 2017-08-30 2018-09-09	40 160
B9	62.34478	-116.48088	9	2015-06-09 2015-08-12 2016-05-11 2016-09-14 2017-09-05 2018-09-12	40 80 160
B10	62.44933	-116.49620	7	2015-06-09 2015-08-20 2016-05-16 2016-09-13 2017-09-05 2018-09-12	40 80 160
B11	62.48020	-116.51913	6	2015-06-06 2015-08-20 2016-05-15 2017-09-06 2018-09-11	40 80 160

B12	62.48088	-116.52031	9	2015-06-06 2015-08-20 2016-05-20 2016-09-15 2017-09-06 2018-09-11	40 80
B13	62.48500	-116.51748	9	2015-06-10 2015-08-19 2016-06-03 2016-09-15 2017-09-05 2018-09-10	40 80
B14	62.52220	-113.38200	4	2016-06-16 2016-09-12 2017-09-07 2018-09-14	160
B15	63.13341	-114.00413	4	2015-06-18 2015-08-30 2016-09-10 2018-08-25	160
B16	63.13244	-114.00634	7	2015-06-18 2015-08-30 2016-09-11 2018-08-25	160
UB1	60.93496	-117.07239	2	2017-08-23 2018-09-04	80
UB2	62.02892	-116.31390	4	2016-05-18 2016-09-09 2017-09-03 2018-09-10	160
UB3	62.45825	-114.53160	6	2015-06-07 2015-08-11 2016-05-31 2016-09-16 2017-09-07 2018-09-13	160

Mean apparent resistivity values for the burned study sites from 2015 to 2018 were extracted and exhibit no significant change through time, due to the large range in resistivity values across study sites and dampening by the inclusion of unfrozen portions of the surveys, particularly where dry sand without permafrost exhibits high apparent resistivities (Figure 3).

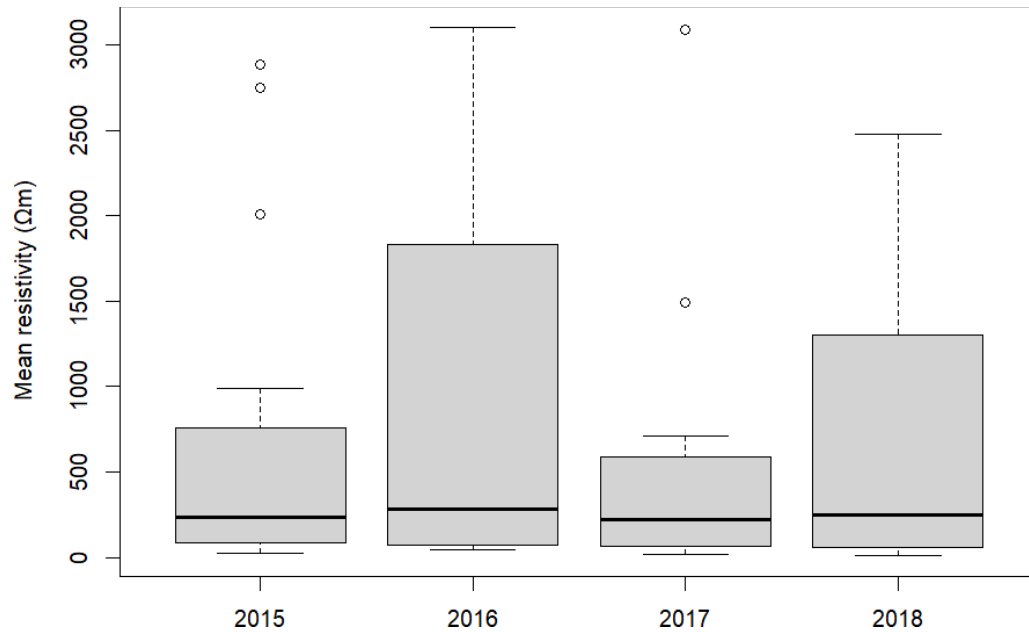


Figure 3. Mean apparent resistivity from electrical resistivity tomography surveys conducted at burned study sites (B1-B16) from 2015 to 2018. Note the difference in the y-axis in Figure 4.

A decline in mean apparent resistivities from 2015 to 2018 is statistically significant (p -value < 0.05) for a subset of the burned study sites, B1 through B13, all of which are within the Taiga Plains ecozone and are characterized by relatively thin permafrost (Figure 4). This indicates an increase in unfrozen moisture content and a decrease in ice content at these sites. The northernmost sites within the Taiga Shield ecozone, B14, B15, and B16, with permafrost thicknesses of at least 24 m, have much higher resistivities than study sites B1 through B13, given their higher ground ice contents and thicker and colder permafrost.

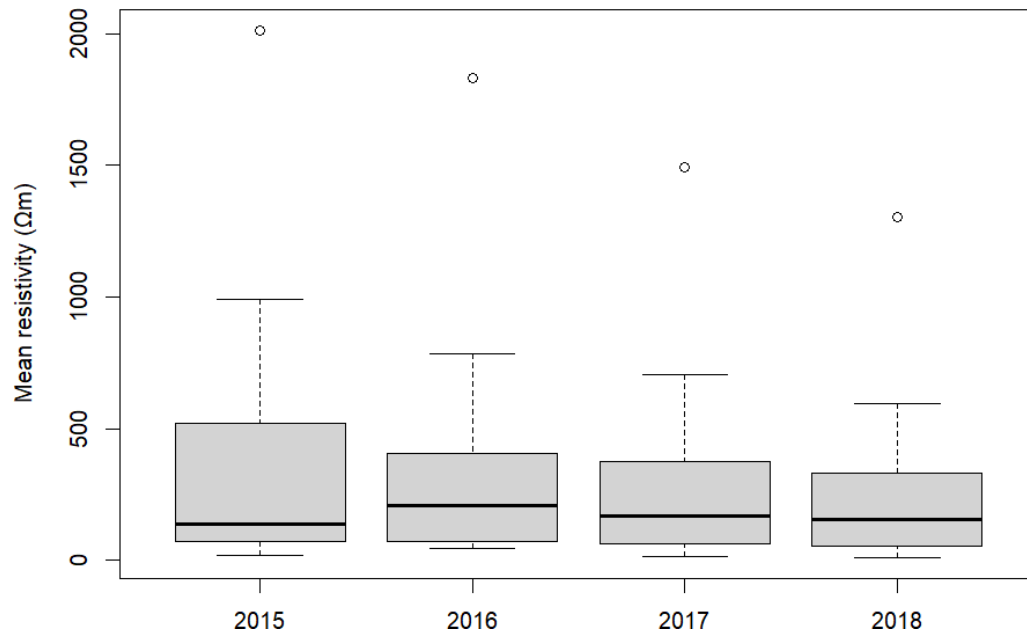


Figure 4. Mean apparent resistivity from electrical resistivity tomography surveys conducted at burned study sites (B1-B13) from 2015 to 2018. Note the difference in the y-axis in Figure 3.

These data provide a baseline from which to measure future permafrost response to wildfire in northern Canada and complement other existing ERT datasets from the region collected by the Geological Survey of Canada (Oldenborger 2012).

Acknowledgements

Financial support for the collection of this field data was provided by the Government of Northwest Territories Cumulative Impact Monitoring Program (Project #170), the Natural Sciences and Engineering Research Council Discovery Grant Program, the Weston Family Foundation, the Northern Scientific Training Program, the Royal Canadian Geographical Society, the University of Ottawa, and the Geological Survey of Canada. Field logistics support was provided by Merritt Turetsky, Jennifer Baltzer, and Steven Cumming. Field assistance was provided by Kirsten Reid, Lucas Brehaut, Nicola Day, Xanthe Walker, Geneviève Degré-Timmons, Julie Trus, Tom Douglas, Catherine Dieleman, Brittany Main, Kevin Stones, and Moya Painter. Brendan O'Neill provided helpful comments.

References

- Environment and Climate Change Canada. 2025. Canadian Climate Normals.
- Fortier, R., LeBlanc, A.-M., Allard, M., Buteau, S., and Calmels, F. 2008. Internal structure and conditions of permafrost mounds at Umiujaq in Nunavik, Canada, inferred from field investigation and electrical resistivity tomography. *Canadian Journal of Earth Sciences*, **45**(3): 367–387. doi:10.1139/E08-004.
- Gibson, C.M., Chasmer, L.E., Thompson, D.K., Quinton, W.L., Flannigan, M.D., and Olefeldt, D. 2018. Wildfire as a major driver of recent permafrost thaw in boreal peatlands. *Nature Communications*, **9**(1): 3041. doi:10.1038/s41467-018-05457-1.
- Government of Northwest Territories. 2008. Ecosystem classification.
- Hauck, C., Isaksen, K., Vonder Mühll, D., and Sollid, J.L. 2004. Geophysical surveys designed to delineate the altitudinal limit of mountain permafrost: an example from Jotunheimen, Norway. *Permafrost and Periglacial Processes*, **15**(3): 191–205. doi:10.1002/ppp.493.
- Heginbottom, J.A., Dubreuil, M.-A., and Harker, P. 1995. Canada, Permafrost (National Atlas of Canada, 5th Edition). Natural Resources Canada,. doi:10.4095/294672.
- Herring, T., Lewkowicz, A.G., Hauck, C., Hilbich, C., Mollaret, C., Oldenborger, G.A., Uhlemann, S., Farzamian, M., Calmels, F., and Scandroglio, R. 2023. Best practices for using electrical resistivity tomography to investigate permafrost. *Permafrost and Periglacial Processes*, **34**(4): 494–512. doi:10.1002/ppp.2207.
- Holloway, J. 2020. Impacts of forest fire on permafrost in the discontinuous zones of northwestern Canada. PhD, University of Ottawa, Ottawa, Canada.
- Mackay, J.R. 1977. Probing for the bottom of the active layer. Geological Survey of Canada, **Paper 77-1A**: 327–328.
- Morse, P.D., Wolfe, S.A., Kokelj, S.V., and Gaanderse, A.J.R. 2016. The occurrence and thermal disequilibrium state of permafrost in forest ecotopes of the Great Slave Region, Northwest Territories, Canada. *Permafrost and Periglacial Processes*, **27**(2): 145–162. doi:10.1002/ppp.1858.
- Northwest Territories Centre for Geomatics. 2015. Fire history.
- Oldenborger, G.A. 2012. Electrical resistivity surveys for permafrost terrain characterization along the Highway 3 corridor, Yellowknife, Northwest Territories. Geological Survey of Canada, **Open File 7062**: 39. doi:10.4095/291335.
- Smith, S.L., Burgess, M.M., and Riseborough, D.W. 2008. Ground temperature and thaw settlement in frozen peatlands along the Norman Wells Pipeline Corridor, NWT Canada:

- 22 years of monitoring. *In* Proceedings of the 9th International Conference on Permafrost. Institute of Northern Engineering, University of Alaska Fairbanks. pp. 1665–1670.
- Smith, S.L., Riseborough, D.W., and Bonnaventure, P.P. 2015. Eighteen year record of forest fire effects on ground thermal regimes and permafrost in the Central Mackenzie Valley, NWT, Canada. *Permafrost and Periglacial Processes*, **26**(4): 289–303. doi:10.1002/ppp.1849.
- Way, R.G., Lewkowicz, A.G., Wang, Y., and McCarney, P. 2021. Permafrost investigations below the marine limit at Nain, Nunatsiavut, Canada. *American Society of Civil Engineers*. pp. 33–48.
- Way, R.G., Lewkowicz, A.G., and Zhang, Y. 2018. Characteristics and fate of isolated permafrost patches in coastal Labrador, Canada. *The Cryosphere*, **12**(8): 2667–2688. doi:10.5194/tc-12-2667-2018.
- Wolfe, S.A., Morse, P.D., Hoeve, T.E., Sladen, W.E., Kokelj, S.V., and Arenson, L.U. 2015. Disequilibrium permafrost conditions on NWT Highway 3. *In* Proceedings of GeoQuebec 2015. Quebec, Canada. pp. 1–8.