PERFORMANCE OF FIVE DRILLING WASTE SUMPS, MACKENZIE DELTA, WESTERN ARCTIC CANADA

Carleton University

Rae Landriau MSc. student
Supervisor Dr. Chris Burn

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INTRODUCTION

Climatic warming in northwest Canada has raised the temperature of near-surface permafrost, increasing the potential for failure of sumps constructed in the Mackenzie Delta. This study uses geophysical and sampling methods to investigate stability of 5 sumps. The full paper can be found in the Proceedings of the Twelfth International Conference on Permafrost, volume 1.

LEGACY DRILLING WASTE SITES

Since 1920, the Northwest Territories has been an area of oil and gas exploration and development. To facilitate drilling in permafrost settings freezing point depressants are added to drilling fluids, to ensure that they do not freeze downhole. In the Canadian western Arctic these fluids were disposed of within sumps, large, man-made pits blasted in permafrost. There are over 220 sumps in the western Arctic including Mackenzie delta and adjacent uplands. During sump development, it was assumed that the permafrost would remain frozen in perpetuity and contain the drilling fluids in situ. The stability of sumps has been of increasing concern recently because climate change, increased vegetation growth, and the shifting of weather patterns have impacted the condition of permafrost surrounding the sumps.

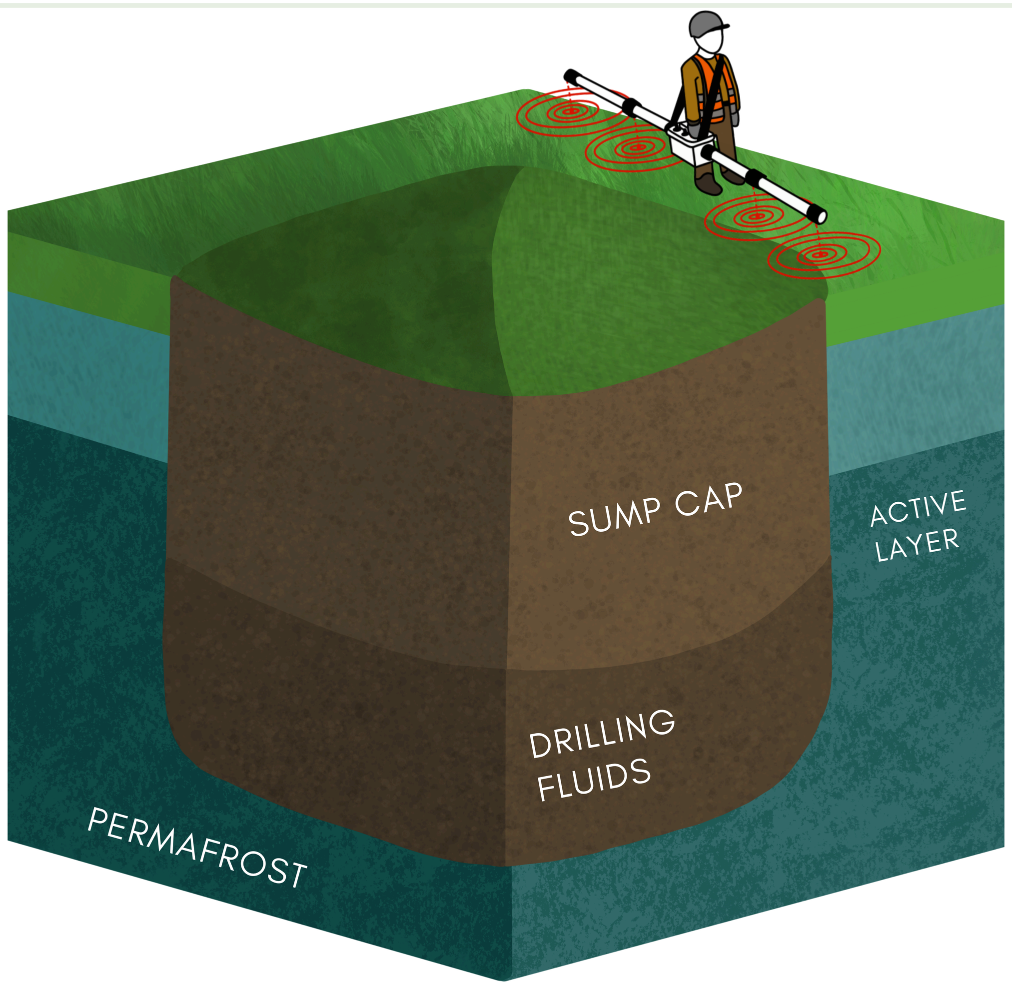

Figure 1. Diagrammatic sketch of EM-31 instrument conducting a field survey on a sump.

THE MACKENZIE DELTA

This dynamic environment has shifting channels and thousands of lakes at various stages of expansion, drainage, and infilling. These sediments are dominantly fine sand and silts. The outer Delta area is underlain by continuous permafrost. Mean annual ground temperatures in undisturbed ground range from -3 to -5°C at the top of permafrost.

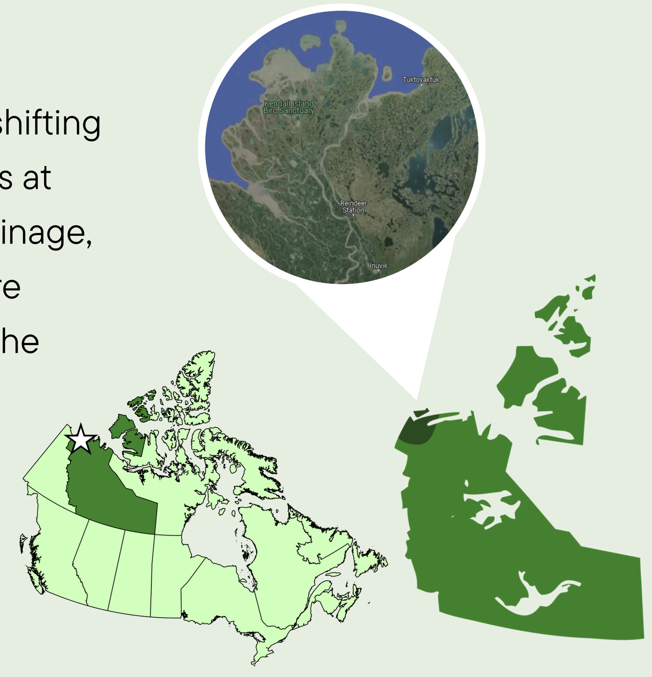

Figure 2. Mackenzie Delta, Northwest Territories.

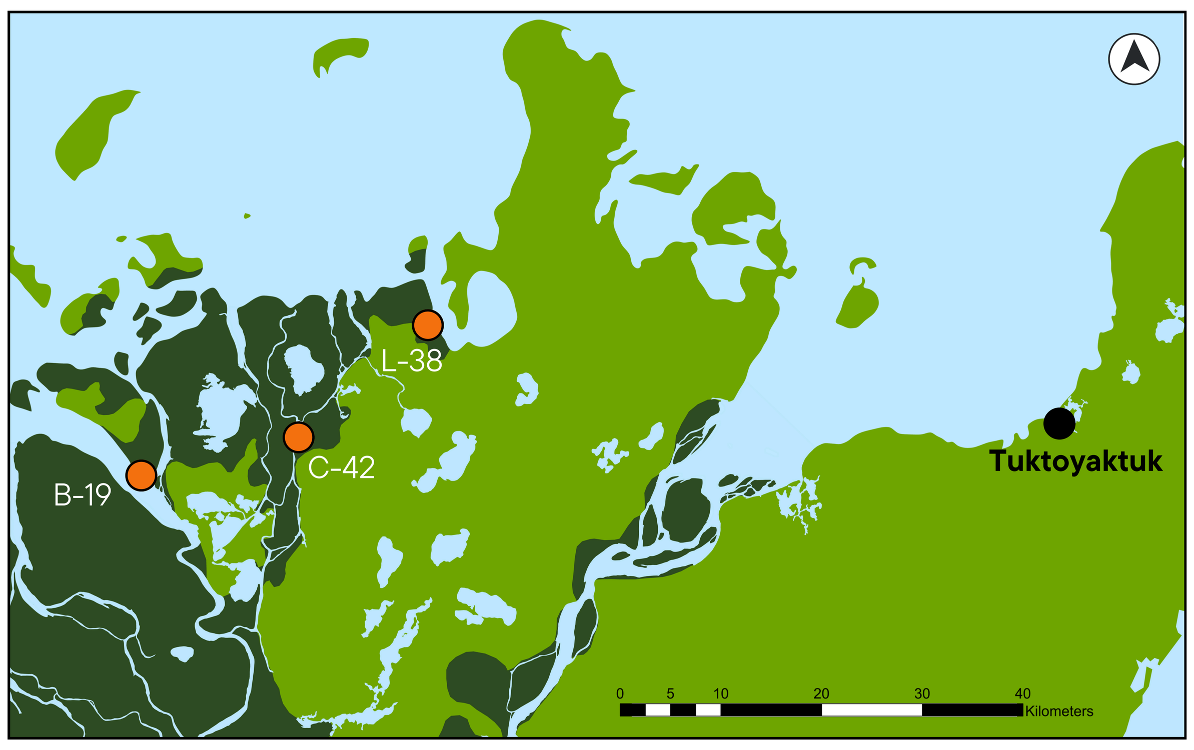

Figure 3. Study area including locations of sumps B-19, C-42, and L-38 which represents 2L-38 and 3/4/5L-38 as well.

OBJECTIVES

- Investigate the stability of sumps in similar permafrost, sediment, and vegetation conditions
- Investigate contaminant migration away from sumps and compare 2022 field data with past data
- Assist in determining a priority order for continued monitoring by regional agencies by determining which sumps are more susceptible to failure/exhibit higher risk

METHODOLOGY

- Surveys of the sumps were conducted in 2022 with a Geonics EM-31 instrument. The EM-31 induces an electromagnetic field in the ground and, with vertical dipole orientation, has penetration of 5 m.
- Aerial photographs were taken 2022 at each site. General characteristics of the site including the percentage of sump cap that was covered by ponds were calculated
- The conductivity of pond water was obtained with a YSI Pro 1030 conductivity meter at Carleton University

Table 1. Conductivity of pond water on and adjacent to sumps (mS/m). For comparison with ground conductivity

SUMP	LOCATION	CONDUCTIVITY
B-19	60 m North of sump cap	29.4
	North side of sump cap	88.3
	South side of sump cap	75.0
C-42	60 m South of sump	126.8
	West of sump cap	30.2
	20 m East of sump cap	65.9
	40 m South of sump cap	47.4
L-38	10 m South West	127.6
	West side sump cap	151.4
2L-38	West side sump cap	147.2
3/4/5 L-38	South East sump cap	128.3
Mackenzie Delta Water		30.0
Ocean Water		5500
Deionized Water		17.3

Figure 4. Aerial photo of sump B-19, August 2022.

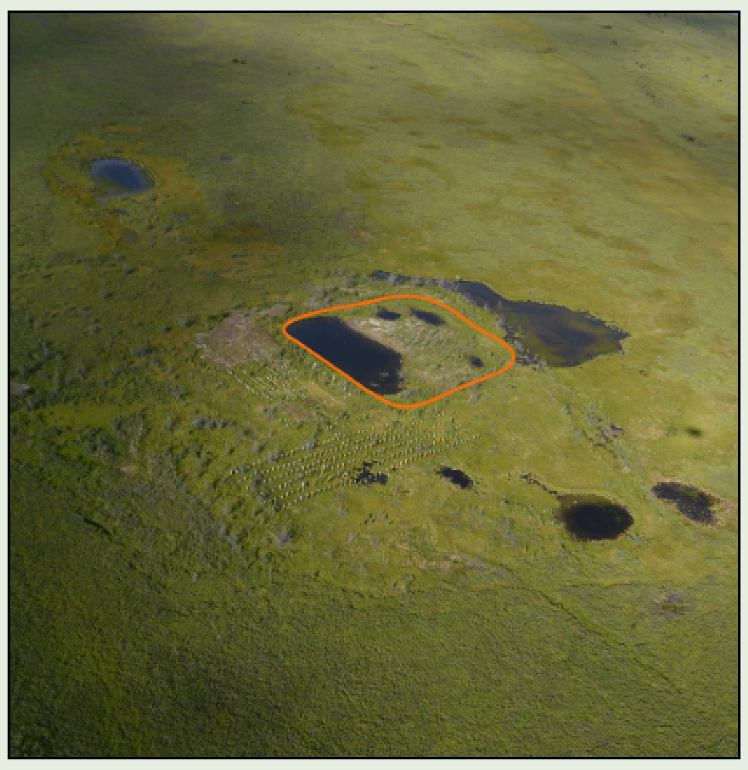

Figure 5. Aerial photo of sump C-42, August 2022.

Figure 6. Aerial photo of the Mallik site with sumps L-38, 2 L-38 and 3/4/5 L-38 August 2022.

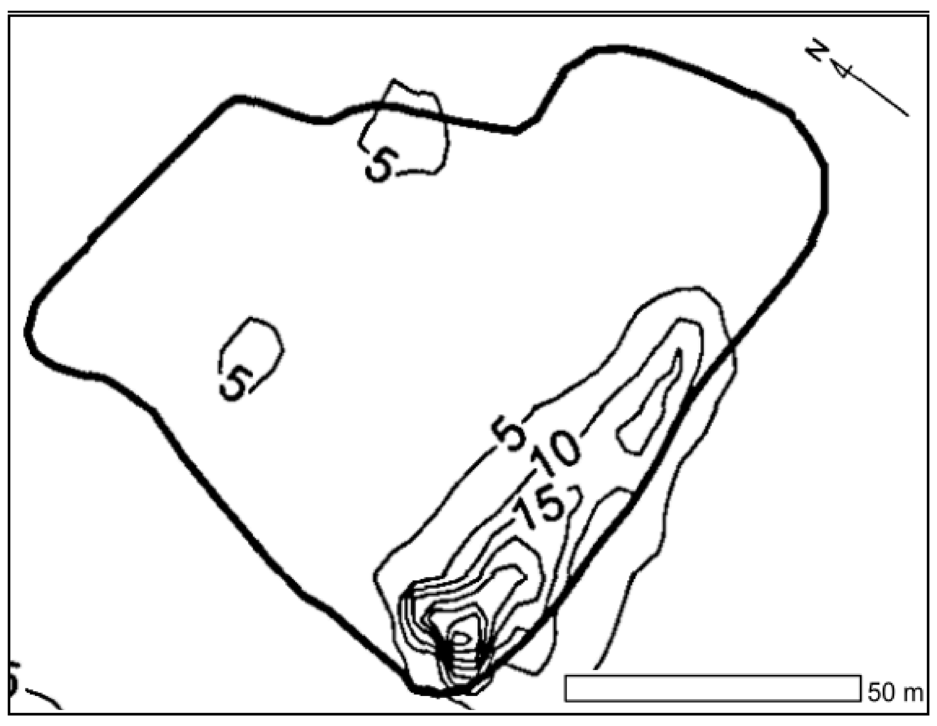

Figure 7. Ground conductivity at B-19 in 2001 (modified from Dyke 2001). Contour lines are at intervals of 5 mS/m.

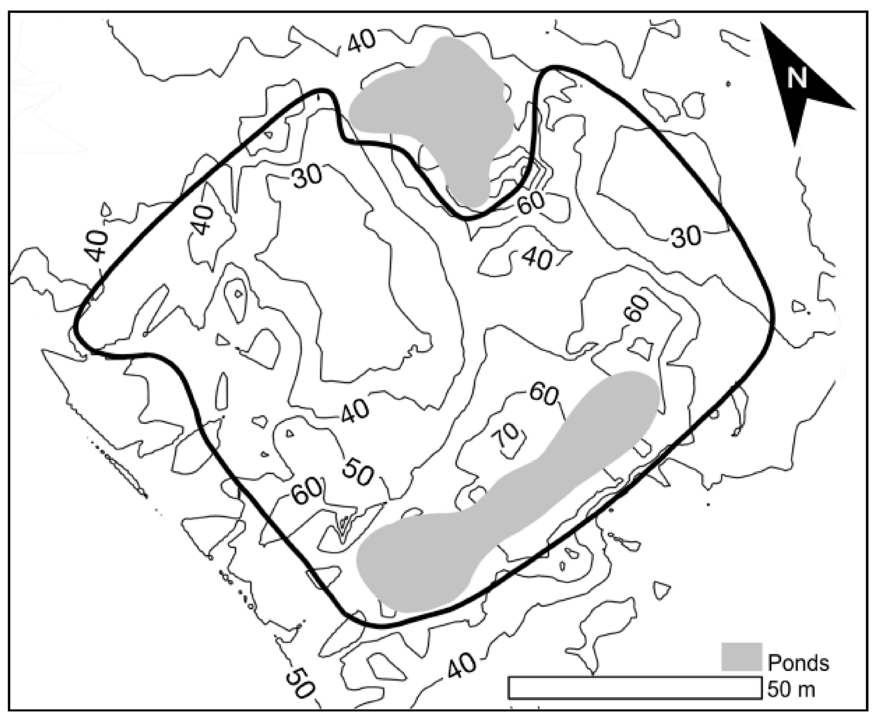

Figure 8. Ground conductivity at B-19 in 2022 Contour lines are at intervals of 10 mS/m.

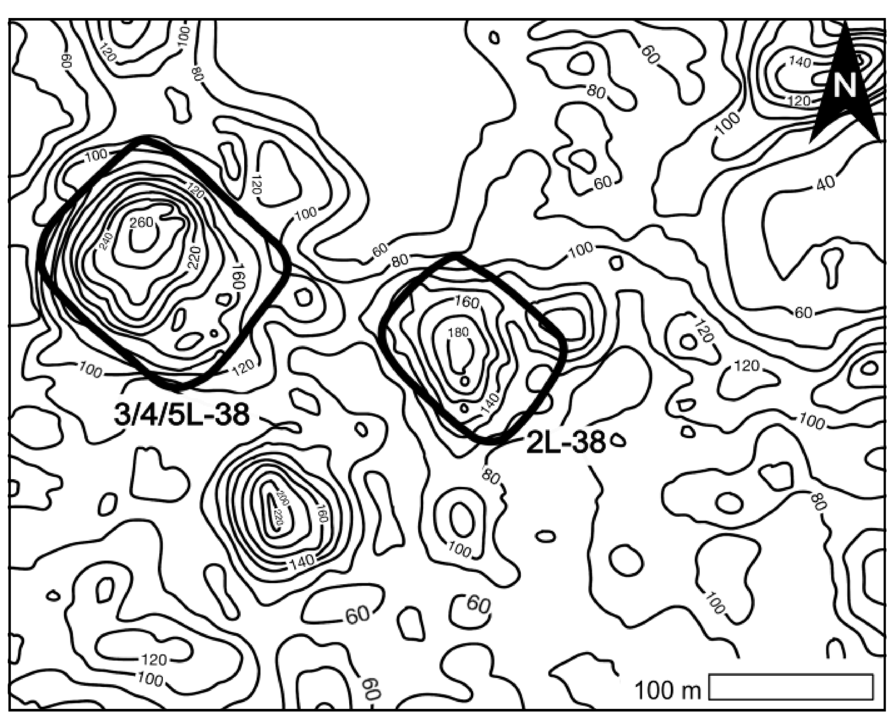

Figure 9. Ground conductivity at Mallik site in 2012 (modified from Piraux et al. 2016). Contour lines are at intervals of 20 mS/m.

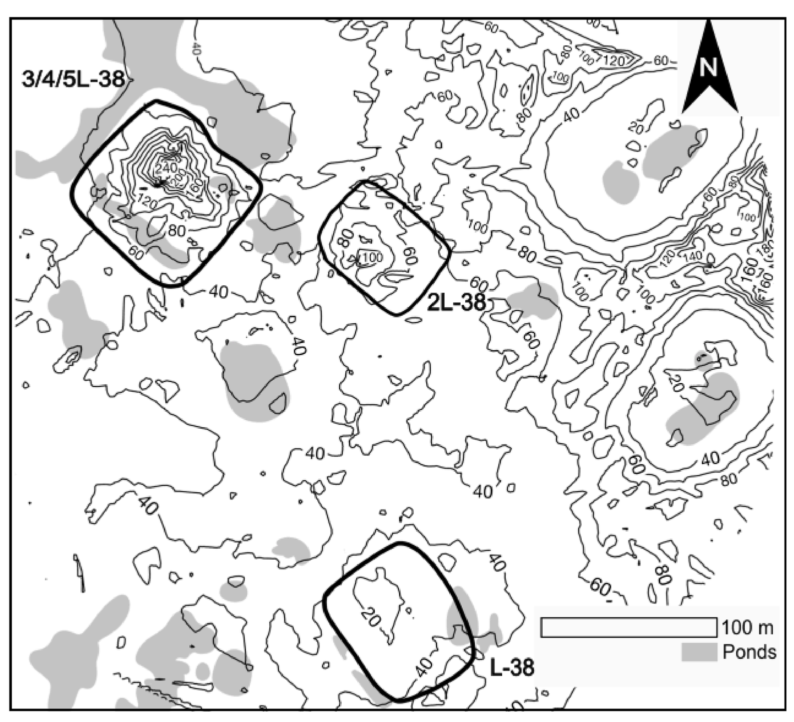

Figure 10. Ground conductivity at Mallik site in 2022. Contour lines are at intervals of 20 mS/m.

PONDING ON SUMPS

The thermal influence of ponds promotes thickening of the active layer and degradation of the subjacent permafrost. All sumps surveyed had ponds on the sump caps.

Table 2. Ponded area of each sump cap.

SUMP	% PONDED
B-19	13
C-42	35
L-38	8
2 L-38	16
3/4/5 L-38	12

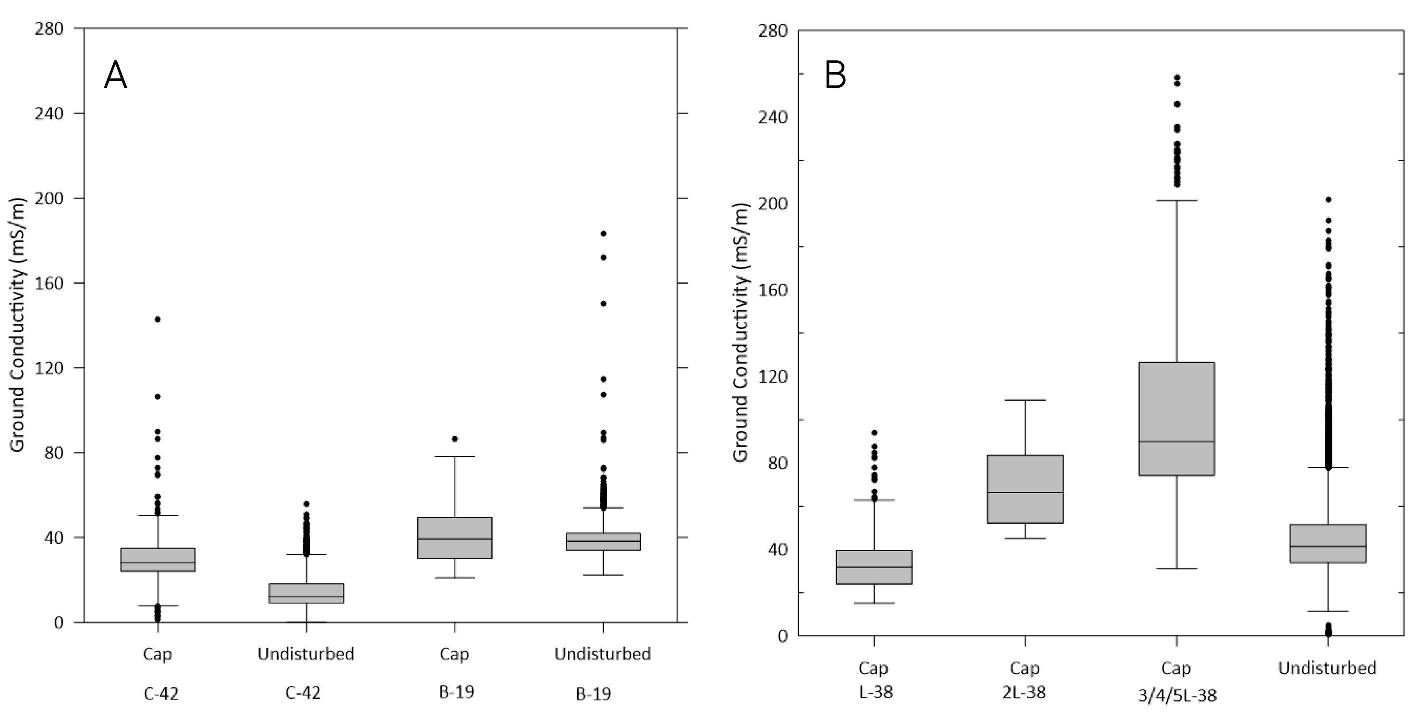

Figure 11. Distribution of ground electrical conductivity measurements between sump caps and undisturbed terrain (in mS/m) at (A) C-42 and B-19 and (B) Mallik site, at sumps L-38, 2L-38 and 3/4/5L-38. Data collected in August 2022.

RESULTS AND DISCUSSION

- The distribution of conductivity measurements caps of B-19, C-42, and L-38 were of similar value and consistent with data from undisturbed ground. These sumps were built in the 1970s.
- Data from the cap of 2 L-38 were elevated above the values from the older sumps, and data from 3/4/5 L-38 were the highest recorded from sump caps.
- The conductivities of pond-water samples, presented in Table 1, show elevated salt concentrations from pools on sumps at Mallik (highest at L-38 and lowest at 3/4/5 L-38) and B-19 in comparison with undisturbed terrain. The values from C-42 are comparable between ponds on and off the sump.

CONCLUSIONS

- The electrical conductivity of the ground and pond waters at three sumps in low-lying areas of the outer Mackenzie Delta suggest that sumps built in the 1970s have failed to contain saline waste because the ground conductivity at these sumps is similar to undisturbed ground.
- Mallik 3/4/5 L-38, built in 2002, remains clearly distinguishable by its elevated ground conductivity. This sump appears to be performing relatively well.
- 2 L-38, built in 1998, data suggests that some of this sump's contents may have dispersed between 2012, the date of a previous EM survey, and 2022.

ACKNOWLEDGEMENTS

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