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Influence of terrain and highway construction on thermokarst distribution, North Slave region, NWT, Canada

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Permafrost degradation has been observed throughout the north and is expected to have broad reaching effects on the land and its people. Nevertheless, for much of Northern Canada little quantified information about thermokarst exists. For example, in the southern North Slave region, NWT, thermokarst distribution has never been assessed though permafrost is in thermal disequilibrium and modelling suggests permafrost extent will decline. Additionally, differential subsidence has been observed in the subarctic city of Yellowknife and along highway infrastructure connecting it to the south. To better understand present and future permafrost conditions, we mapped the location and size of thermokarst ponding (a change from forest cover to water) in the study area by comparing historic and modern remotely sensed data sets available from 1945, 1961, and 2005. These data were used to evaluate the dominant terrain controls on the distribution of thermokarst in the region, and the potential influence that highway construction may have had on thermokarst development.

Historically, discontinuous permafrost developed in a time-transgressive manner during the Holocene as lake-level receded from glacial Lake McConnell to present-day Great Slave Lake (5 mm·a^{-1} over the last 8000 years). As a consequence of inundation the upland areas are characterized by extensive wave-washed bedrock outcrops with glaciolacustrine (GL) sediments and glaciofluvial materials occurring between them, whereas the lowland areas feature prominent GL deposits that cover nearly 70 % of the exposed surface. Throughout much of the region ground ice accumulation likely accompanied permafrost aggradation into fine-grained sediments, as is evident by lithalsa growth in particular.

Highway 3, constructed during the mid-1960s, was preferentially aligned to crossed terrain underlain by fine-grained sediments to avoid bedrock and waterbodies. Local silt and clay used for highway embankment construction was sourced from shallow borrow pits developed along the right-of-way. Following construction, many borrow pits developed into ponds.

Thermokarst ponding is widespread in the study area (n = 3138). The transition of approximately 3.57 km^2 of land cover from forested permafrost terrain to ponds is different than in the low subarctic where permafrost peatlands degrade to fens. Most ponds are small ($<$ 5000 m^2), but range up to nearly 45 000 m^2. Pond distribution relates to surficial geology and elevation, with ponds dominantly constrained to GL deposits, and decreased pond counts with increased elevation. Highway construction has substantially affected thermokarst development. Compared to pond density within undisturbed GL deposits, pond density is an order of magnitude greater in the vicinity of Highway 3, where about half of the borrow pits have developed thermokarst ponds within them. In contrast, only 6.5 % of ponds within 200 m of the highway developed before 1961.

Thermokarst is likely widespread throughout the region as GL deposits are extensive. Reduced thermokarst ponding at higher elevation is likely related to reduced GL extent, but may also be related to more time for past thermokarst development given the landscape history. Regardless, future thermokarst development will continue to be associated with permafrost in low lying forested GL deposits that should be avoided by new infrastructure construction.