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$\gamma_b \Delta^c \dot{\gamma} \Pi \sigma^b \quad \Lambda c_n \nabla^f b^f \sigma \nabla n \nabla^a L^a \sigma^b$

An ice core on Müller Ice CapDr. Dorte Dahl-Jensen, University of ManitobaWe (a group of scientists from the Centre for Earth Observation Science at the University of Manitoba) plan to drill an ice core through Müller Ice Cap on Axel Heiberg Island. This core will be 10 cm in diameter and ~600 m long and will contain information about climate in Arctic Canada thousands of years ago. This core will help answer:

- Did sea ice conditions respond to climate during the past 20,000 years?
- What climatic conditions did arctic ice caps experience during the past and how did they respond?
- How old is Müller Ice Cap?
- How fast is Müller Ice Cap shrinking, and how much is climate warming there?

We can use new measurement techniques to address these questions before warming melts the records in the ice cap. The project involves going to Axel Heiberg Island twice, once to pick the exact site of the core and once to drill. In 2023, we plan to have a team of five survey the ice cap with an ice-penetrating radar and collect some small snow samples. The radar does not affect people or animals but will identify the drill site that contains the most information about past climate. In 2024, about 12 people will spend 2-3 months camping on the glacier, drilling the core, and making measurements on the surrounding snow. The core will be sent back to laboratories to determine past temperature, snowfall and sea-ice conditions in the area. The measurements will inform models of the past, present, and future evolution of Müller Ice Cap. The ice and snow we collect will have minimal environmental impact; in total, we plan to collect less than 10 m<sup>3</sup>, and additional snow melted for camp use will be less than 1 m<sup>3</sup> per day. The primary environmental impact will be that we must put a non-freezing fluid in the hole so that it does not close around the drill. We plan to leave the fluid in the hole afterwards to allow future measurements of the ice flow and temperature (and since it is difficult to remove), as is done in Greenland and Antarctica. The fluid will be safely contained in the ice cap and is non-hazardous. In addition, the location of the work is over 400 km from Grise Fiord or Resolute, and will be in the centre of the glacier, far from wildlife. Data will be made available through the Canadian Watershed Information Network (CanWIN), a permanent online archive. An archive of the ice itself will be kept at the Canadian Ice Core Laboratory for future use. The results will be shared through consultations in Grise Fiord and Resolute, where data from the deep past can be integrated with knowledge from the communities. We hope these results can guide future community-led research on glaciers closer to the communities, and we have applied for funding from CFI to help make that possible (evaluation in June 2023). During 2024 we hope to employ 1-2 residents of Resolute or Grise Fiord for work on the ice cap—this could involve logistics, camp management, or cooking.

ᐅᐃᐱᑎᓂᓪ: n/a (Project is solely in North Baffin, closest communities are Resolute Bay and Grise Fiord)

[illegible]

Operations Phase: from 2023-03-26 to 2024-08-25

Λ ϵ η Δ η ζ Δ σ Δ <sup>96</sup> )<sup>c</sup>

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|--|--|---------------|---|---|---|
| Area of Muller ice cap which we will survey-we plan to camp and drill an ice core at one point in this area. | Scientific/International Polar Year Research | Crown         | The centre of Muller Ice Cap has, to our knowledge, been visited only by scientists. There were scientific surveys performed from 1959-1962 by McGill University. The site has a weather station installed by Queen's University in 2021. | Although Inuit have inhabited Axel Heiberg Island in the past, the available evidence suggests that was far from our proposed site, near the east coast of the island and not on the ice cap. Our proposed site has no known archaeological value, and is more than 50 km from the closest archaeological sites near Buchanan Lake. | Axel Heiberg Island is currently uninhabited. The proposed site is about 50 km from the Napaqtulik/Napurtulik Proposed Territorial Park. It is about 440 km from Grise Fiord and 580 km from Resolute Bay, the two nearest communities. |

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| ᐱᐅᑦᐱᑦᑎᔪᑦ | Marty Kuluguqtup, Senior Administrative Officer | Hamlet of Grise Fiord | 2022-07-06              |

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North Baffin

ᑕᐃᕐᕐᑦ ᐱᑭᑦᐃᑦ ᐃᕐᕐᑦᑕᐃᕐᑕ

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| ᐱᕐᑕᐃᕐᑕᐃᕐᑕᐃᕐᑕ<br>ᐱᕐᑕᐃᕐᑕᐃᕐᑕᐃᕐᑕ  | We have forwarded the NPC conformity description to NWB and are in the process of applying for a Type B license.             | Not Yet Applied  |  |  |
| ᐱᕐᑕᐃᕐᑕᐃᕐᑕᐃᕐᑕ<br>ᐱᕐᑕᐃᕐᑕᐃᕐᑕᐃᕐᑕ  | We are preparing an application for a Research License, and will be submitting that application shortly.                     | Not Yet Applied  |  |  |

Project transportation types

| Transportation Type | ᐱᕐᑕᐃᕐᑕᐃᕐᑕᐃᕐᑕ   | Length of Use |
|---------------------|--|---------------|
| Air                 | We will reach the site by Twin Otter from Resolute and Eureka  |               |
| Land                | On site, we will use snowmobiles for surveying. We will use two snowmobiles pulling sleds to do this work. |               |

Project accomodation types

Temporary Camp

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Λ<sup>9</sup>d<sup>c</sup> d<sup>a</sup>r<sup>z</sup><sup>9b</sup> d<sup>9b</sup>CdσD<sup>4</sup>z<sup>9b</sup> Δc<sup>9b</sup>r<sup>7</sup>Dn<sup>3</sup>r<sup>c</sup> ΔjCΔ<sup>c</sup>, Γ<sup>c</sup>→dPñ<sup>c</sup>, <sup>9b</sup>b<sup>9b</sup>Lc<sup>j</sup><sup>9b</sup>, με<sup>r</sup>D<sup>c</sup> d<sup>r</sup><sup>a</sup>r<sup>c</sup>→

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|-------------------------------------|--------|-------------------------|--|
| Drill                               | 1      | 1x2x6 m                 | Needed to drill an ice core through Mueller Ice Cap. Drill designed to recover a 4 inch diameter core in 1-2 meter sections. Will also be used to recover a small sample of rock beneath the ice.                    |
| Ice-penetrating radar               | 1      | 2x2x2 m                 | Needed to determine optimal site to drill. Will be driven across the surface of the ice behind a snowmobile in order to measure ice thickness and layering in the ice.   |
| Snowmobile                          | 2      | 1x1x2 m                 | Used for moving around the ice cap and towing radar.   |
| Basler or Twin Otter                | 1      | 21x29x5 m               | Transportation from Eureka or Resolute to the ice cap.   |
| Large tents                         | 3      | 8x4x5 m                 | Shelter while drilling, eating, working, etc.  |
| Personal tents                      | 12     | 2x2x1 m                 | Sleeping during work.  |
| Generator                           | 3      | 1x1x2 m                 | 2 gasoline and 1 diesel generator, used to power radar, drill, and camp.   |
| Ice core analysis unit              | 1      | 0.5x0.5x0.5m            | Used to measure some basic properties of the ice while we are on the ice cap (the majority of analyses will take place back in a laboratory). This analysis melts ice, with no waste other than the resulting water. |

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| Propane                                | fuel                       | 5                      | 100                    | 500                    | Lbs                    |
| Gasoline                               | fuel                       | 3                      | 205                    | 615                    | Liters                 |



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$$\Delta^b C d_{\sigma} \sim \Delta^q \sigma^q$$

| Location | Activity | Volume          | Notes   | Remarks   |
|----------|----------|-----------------|---|---|
| Camp     | Drilling | 9800 L          | We plan to leave the drill liquid, which is a generally safe chemical, in the borehole. This allows future scientists to access the hole if additional measurements are desired. Leaving the fluid like this is standard practice in ice-core drilling, including in sensitive areas. Since the fluid is contained in the hole, and only rises to a level where the ice is impermeable, it does not leak out. At this remote site, there is no risk of it affecting drinking water or impacting wildlife. | The hole will have a cap/casing on top, which prevents anything from getting in and liquid from leaking away. |
| Camp     | Drilling | 15 cubic meters | Sump in glacier, buried after use.  | n/a   |
| Camp     | Drilling | 3 cubic meters  | All non-human camp waste will be flown out.   | n/a   |
| Camp     | Drilling | 2 cubic meters  | We plan to leave only urine in a sump in the glacier.   | Feces will be flown out in buckets.   |

$\Delta \rho_{\text{NFC}}^{\text{C}} = \Delta \rho_{\text{NFC}}^{\text{D}}$

Potential water quality impacts stem from the drill fluid and from fuel use. Drill fluid is needed to keep the hole open during drilling. Leaving this fluid in the hole is standard practice including in sensitive areas (e.g., it is allowed under our permit in the Northeast Greenland National Park). The fluid will be contained in the hole, is not hazardous, and allows for future scientists to make additional measurements if desired. The impact will be mitigated by ensuring that fluid remains within the hole; while safely encased in the hole, the fluid will not harm water quality. Given the distance from the nearest communities, there is no risk of the drill fluid affecting people. The choice of a non-hazardous fluid is a backup in case the fluid escapes, for



example due to climate change destabilizing the ice cap. Risk of fuel spills will be mitigated through the use of berms for all drums, and sufficient spill kits for cleanup; we will fly out any contaminated cleanup materials. There will be some noise from aircraft, generators, and snowmobiles; we will mitigate these effects by eliminating extra flights, using small generators only when needed, and driving at low speeds. Negative impacts on polar bears will be mitigated by minimizing scents in camp and bring non-lethal deterrents in addition to firearms; we expect no other biological impacts. We hope for a positive economic impact by employing a community member for work in our camp during 2024.

# **Additional Information**

**SECTION A1: Project Info**

**SECTION A2: Allweather Road**

**SECTION A3: Winter Road**

**SECTION B1: Project Info**

**SECTION B2: Exploration Activity**

**SECTION B3: Geosciences**

**SECTION B4: Drilling**

**SECTION B5: Stripping**

**SECTION B6: Underground Activity**

**SECTION B7: Waste Rock**

**SECTION B8: Stockpiles**

**SECTION B9: Mine Development**

**SECTION B10: Geology**

**SECTION B11: Mine**

**SECTION B12: Mill**

**SECTION C1: Pits**

**SECTION D1: Facility**

**SECTION D2: Facility Construction**

**SECTION D3: Facility Operation**

**SECTION D4: Vessel Use**

**SECTION E1: Offshore Survey**

**SECTION E2: Nearshore Survey**

**SECTION E3: Vessel Use**

**SECTION F1: Site Cleanup**

The proposed site is all on top of the ice cap and largely devoid of life. There is no vegetation on the ice cap. While some mammals and birds are seen regularly on glaciers, the location of our site away from the ice edge means that there are no food sources for animals near where we plan to work, and thus animal encounters are unlikely. There are four species under the Species at Risk Act whose nominal range includes Axel Heiberg Island: polar bears, Peary caribou, ivory gulls, and the islandica subspecies of Red Knots. Since the site is away from the ocean, at high elevation, and on ice, we expect that Polar bears do not regularly occupy the study site, though it is possible that they occasionally visit. According to the species' recovery plan, community information and surveys agree that the primary Peary Caribou sites on Axel Heiberg Island are east and south of the ice cap, and the migrate from there to the southeast. Environment and Climate Change Canada indicates that they do not generally enter the interior of the ice cap. While the ivory gull

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### Miscellaneous Project Information

உடையவர்களுக்கும் அருள்கூர்ந்து உதவி செய்து கொடுப்பதற்காக உமது அருள்வழியை நான் விரும்புகிறேன்.

## Cumulative Effects

The ice cap has only seen sporadic scientific work over the last 65 years, and to our knowledge there have only been two visits to our study area during the last few decades. The last time people camped within the

study area was in 1962. We thus expect no cumulative impacts on the ground. The project will add a small number of flights to the cumulative aircraft operations in the area, but since the total number of flights is still small we expect the cumulative effect to be low. To the extent possible, we will maximize space on flights and minimize cargo so that there are no more aircraft movements than strictly necessary to complete the work.

## Impacts

$\Delta^{\text{fb}} \subset \Sigma^{\text{fb}} \cap \Gamma^{\text{c}}$      $\Delta^{\text{fb}} \subset \Sigma^{\text{fb}} \cap \Gamma^{\text{c}}$

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| PHYSICAL  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Designated environmental areas                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Ground stability                                      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Permafrost  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Hydrology / Limnology                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Water quality   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Climate conditions                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Eskers and other unique or fragile landscapes         |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Surface and bedrock geology                           |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Sediment and soil quality                             |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tidal processes and bathymetry                        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Air quality   |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Noise levels  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| BIOLOGICAL  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Vegetation  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Wildlife, including habitat and migration patterns    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Birds, including habitat and migration patterns       |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Aquatic species, incl. habitat and migration/spawning |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Wildlife protected areas                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| SOCIO - ECONOMIC                                      |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Archaeological and cultural historic sites            |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Employment  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Community wellness                                    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Community infrastructure                              |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Human health  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |

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|-----------|---|
| 1 polygon | Area of Muller ice cap which we will survey--we plan to camp and drill an ice core at one point in this area. |
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