Memo

To	Manon Turmel and Jennifer Range, Agnico Eagle Mines Limited
From	Greg Sharam and Nina Morrell, ERM Consultants Canada Ltd.
Date	19 May 2023
Reference	0687353-01
Subject	Meliadine Mine Caribou Movement Mapping – Brownian Bridge Movement Models

1. INTRODUCTION

Agnico Eagle Mines Limited (Agnico Eagle) is working to address technical report comments (TRC) from the Government of Nunavut (GN) and the Kivalliq Inuit Association (KivIA). TRC GN-06 requested that Agnico Eagle provide the location of proposed infrastructure in relation to caribou trails, and specifically requested a heat map of collar data during baseline, exploration, construction, and operations at Meliadine Mine.

To address this, ERM produced Brownian Bridge Movement Models (BBMM; heat maps) of caribou occurrence using collar data, divided by mine stage (pre-construction, advanced exploration, and construction/operation) and by season (calving, post-calving, and summer).

1.1 Objectives

The objective of the Brownian Bridge Movement Model is to:

- Evaluate the current state of movement through the mine and proposed windfarm area.
- Evaluate movement by mine stage (pre-construction, advanced exploration, and construction/operation) and by season (calving, post-calving, and summer).

1.2 Background

The Qamanirjuaq caribou subpopulation is a large barren-ground caribou herd numbering approximately 288,000 animals in 2017, down from over 348,000 animals reported in 2008 (Boulanger et al. 2018). A new population survey was conducted in 2022 but the results were not publicly available at the time of this memo. The herd range stretches approximately 1,000 km from Chesterfield Inlet in the north to northern Manitoba in the south, and from Hudson Bay on the east to eastern Northwest Territories and north-eastern Saskatchewan in the west (BQCMB 2014).

The herd generally winters below the treeline in northern Manitoba, Saskatchewan, and the adjoining areas of the Northwest Territories (NWT) and Nunavut. Spring migration is north along the coast of Hudson Bay, past the communities of Arviat, Whale Cove, and Rankin Inlet to a broad calving ground generally centered on Qamanirjuaq Lake (BQCMB 2014).

Following calving, the caribou form into large groups of hundreds to thousands of caribou and radiate out from the calving grounds, including east towards the coast. During June and July, groups of animals from this herd interact with the hamlet of Rankin Inlet, the Meliadine Mine and the All Weather Access Road (AWAR) connecting the two. During summer and fall, the caribou generally move south and inland, gradually returning south towards their wintering areas by early December. The Qamanirjuaq herd have alternated between periods of presence and absence in the terrestrial Regional Study Area (RSA; 28 km radius centered on the mine site) over time.

2. METHODS

Satellite collar data on Qamanirjuaq caribou from 1993 to 2022 was used to estimate caribou distribution relative to the mine, AWAR, lakes, and topography. The general design was to use a BBMM to estimate the probability of caribou occurrence in locations both near and far from the mine and proposed windfarm location. This provides a baseline movement model to evaluate against as the windfarm is constructed.

The raw dataset underwent Quality Analysis/Quality Control (QA/QC) by extracting correct dates and times, longitudes, and latitudes. When available, the data for each individual were filtered to three locations from each day at 8-hour intervals. The data were then screened for any spatial errors. Spatial errors included locations far off the mean and the median location, as well as detected “spikes”. Spikes were classified as locations with high outgoing and incoming speed and sharp turns. Season was assigned to the screened data following GN methods. The data for the calving were further refined to only include location fixes up to 7 days past a parturition event, which were identified based on methods established by Cameron et al. (2018).

The methods for BBMM were developed by Home et al. (2007) and were designed for estimating the expected movement path of an animal using discrete location data. The results are based on the properties of a conditional random walk between successive pairs of locations, which are dependent on the time between locations, the distance between the locations, and the Brownian motion variance that is related to animal’s mobility. To estimate a Brownian Bridge, Brownian motion variance is estimated via maximum likelihood. After the BBMM is fitted to location data, an estimate of the animal’s probability of occurrence can be generated for an area during the time of observation.

For this study, BBMMs were calculated for subsets of data within each season of interest (calving, post-calving, and summer) and within each of three mine stages (Table 2-2), totaling nine BBMMs. The study area was delineated to include the maximum extent of the collar locations during the three seasons of interest. The BBMM output is a 1 km resolution grid covering the study area that contains probability values between 0 and 1. Values can be interpreted as the probability of occurrence for caribou within each grid cell. As a final step in the analysis, the values of the BBMM intersecting the terrestrial RSA and LSA for Meliadine were summarized and tabulated as a percentage to determine the degree of overlap.

Table 2-2: Date Ranges for Mine Life Stages, 1993 to 2022.

Mine Life Stage	Date Range
Pre-Construction Period	1993 - 2011
Advanced Exploration Period	2012 - 2017
Construction and Operation Period	2018 - 2022

3. RESULTS AND DISCUSSION

Collar data from 690 caribou tracks (unique collars each year) over 29 years of data collection were analyzed as part of this study. This included 194 tracks in the pre-construction period (between 3 and 31 collars per year), 244 tracks in the advanced exploration period (between 14 and 75 collars per year), and 252 tracks in the construction/operation period (between 31 and 76 collars per year). Nine BBMMs were generated for each of three seasons and three mine life stages. Values in the outputs range between 0 and 1 and represent the probability that caribou occur in that cell relative to other cells. Probability values are comparable between maps, but it should be noted that in subsets with fewer caribou, the results are more heavily focused on the locations of the individual caribou than in subsets with more caribou. As the data in this study are pooled across several years of data, there is not expected to be a bias towards individuals in any of the subsets. The results are displayed in Figures 3.1-1 through 3.1-9. In general, the study found that:

- The calculated core calving grounds moved north as much as 90 km between the pre-construction period and construction/operation period.
- During calving, the caribou occurrence model did not substantively intersect with the terrestrial RSA during pre-construction and advanced exploration (<0.5% of the range) but did intersect with the RSA during the construction/operation period (14.5%; Table 3-1). There was no overlap in any mine stage with the LSA (Table 3-1).
- During post-calving, the caribou occurrence model intersected with the terrestrial RSA during the advanced exploration period and the construction/operation period but did not substantively intersect the RSA during pre-construction (Table 3-1).
- During summer, the caribou occurrence model intersected with the terrestrial RSA during all three mine life stages, but to a greater extent since 2012 (Table 3-1).
- Qualitative assessment of the results with the underlying satellite imagery indicates an avoidance of large water bodies, including Meliadine Lake, as evidenced by the lower probability values above open water.
- Avoidance of infrastructure (road or mine) is not apparent in qualitative assessment.

Table 3-1: Percent Overlap between Meliadine Terrestrial RSA and BBMM for Select Mine life stages and seasons.

Mine Life Stage	Season	Percent overlap with RSA	Percent overlap with LSA
Pre-Construction Period (1993-2012)	Calving	0.0%	0.00%
Advanced Exploration Period (2012-2017)	Calving	0.3%	0.00%
Construction and Operation Period (2018-2022)	Calving	14.5%	0.00%
Pre-Construction Period (1993-2012)	Post-Calving	0.1%	0.00%
Advanced Exploration Period (2012-2017)	Post-Calving	4.7%	0.00%
Construction and Operation Period (2018-2022)	Post-Calving	36.8%	0.43%
Pre-Construction Period (1993-2012)	Summer	3.2%	0.00%
Advanced Exploration Period (2012-2017)	Summer	18.8%	0.42%
Construction and Operation Period (2018-2022)	Summer	17.5%	0.44%

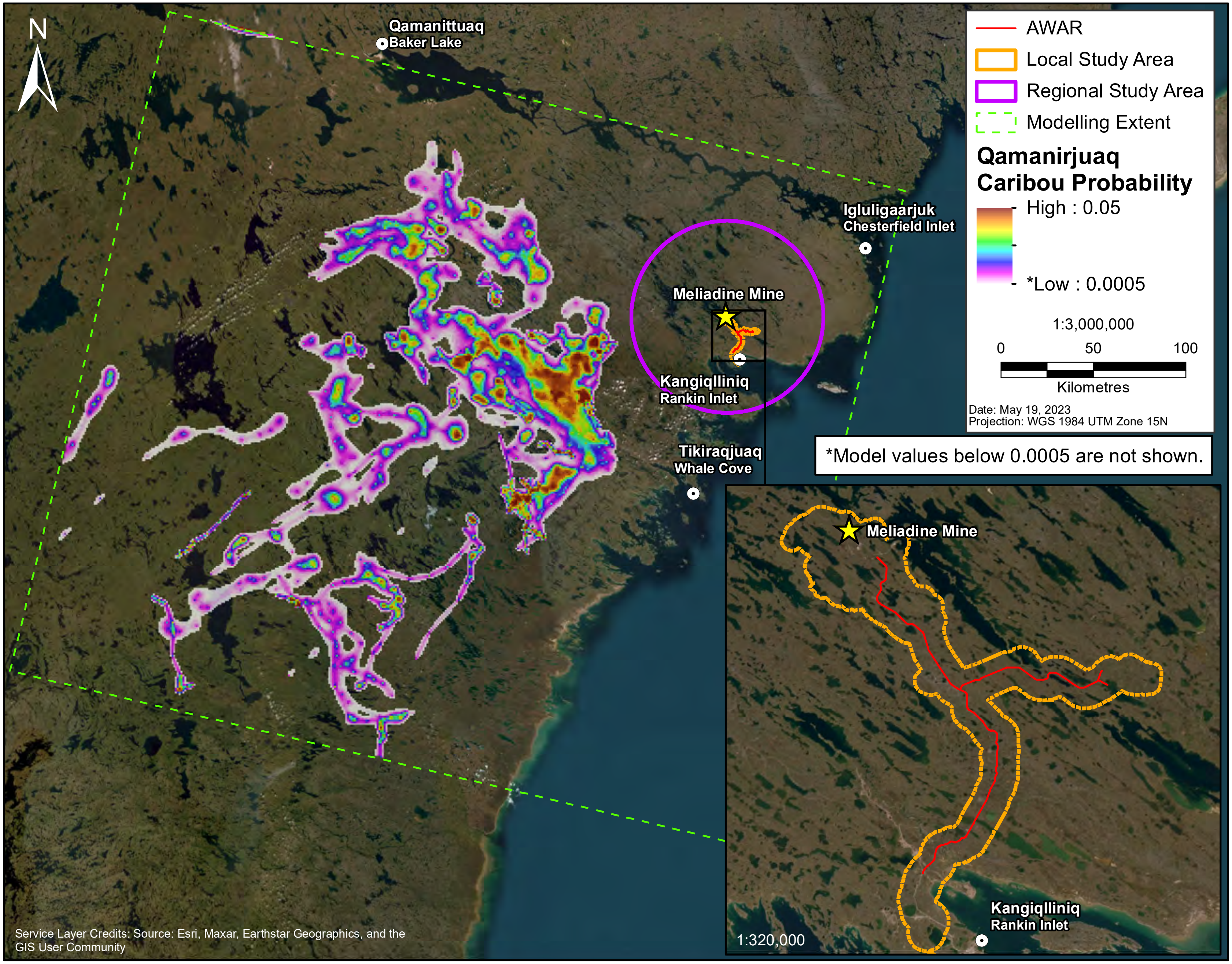

Figure 3.1-1: BBMM for Qamanirjuaq Herd during Calving, Pre-Construction Period (1993-2011)

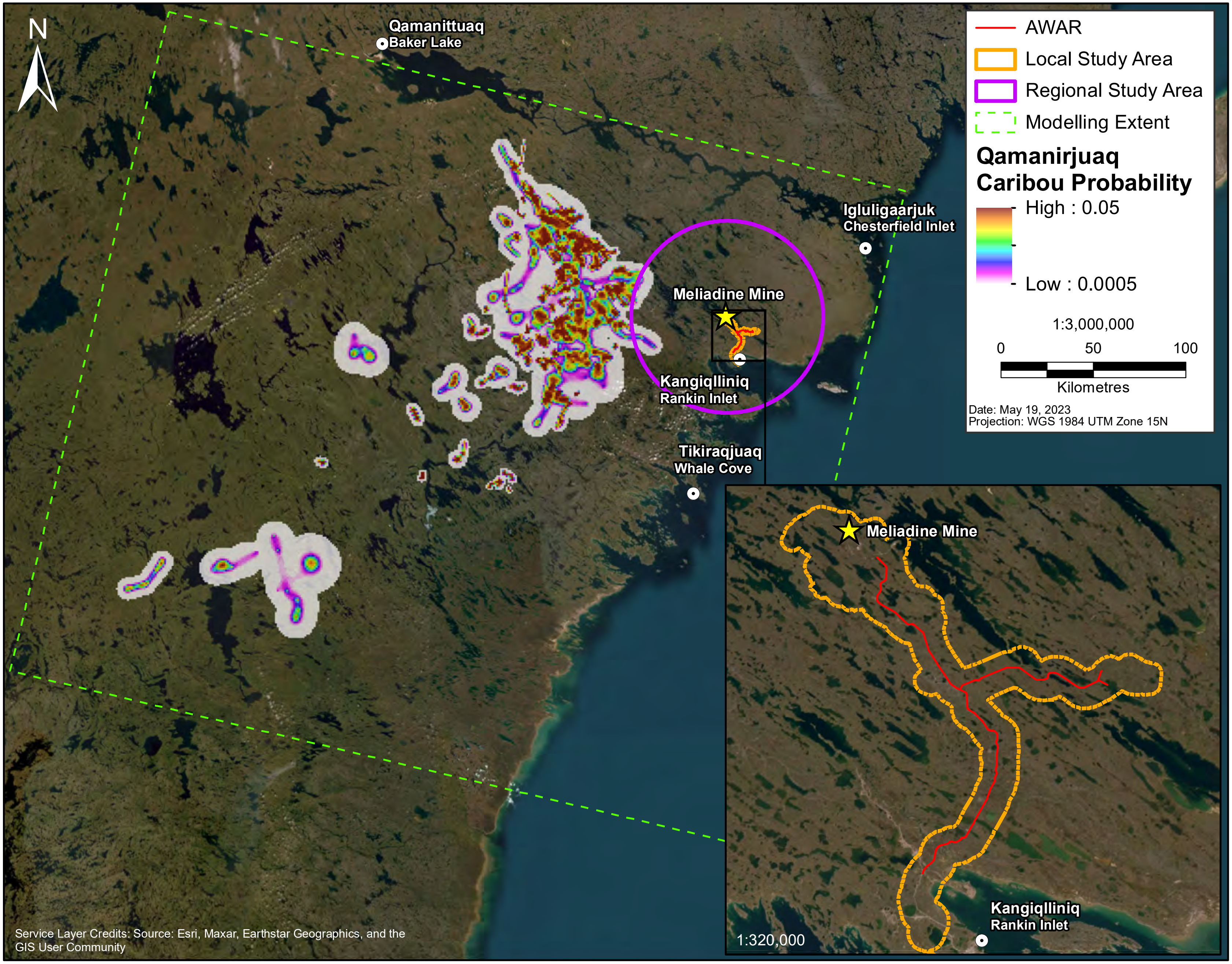

Figure 3.1-2: BBMM for Qamanirjuaq Herd during Calving, Advanced Exploration Period (2012-2017)

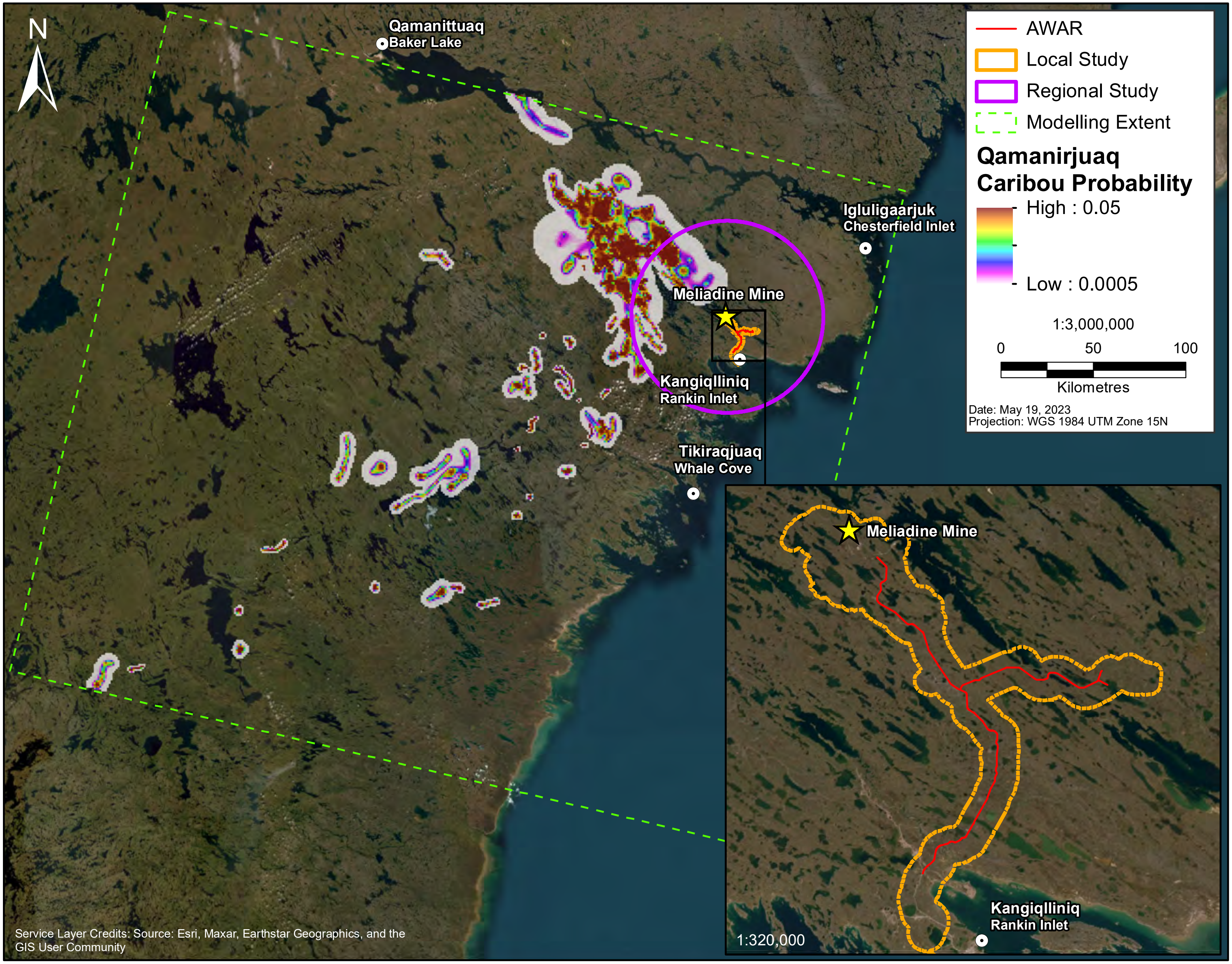

Figure 3.1-3: BBMM for Qamanirjuaq Herd during Calving, Construction and Operation Period (2018-2022)

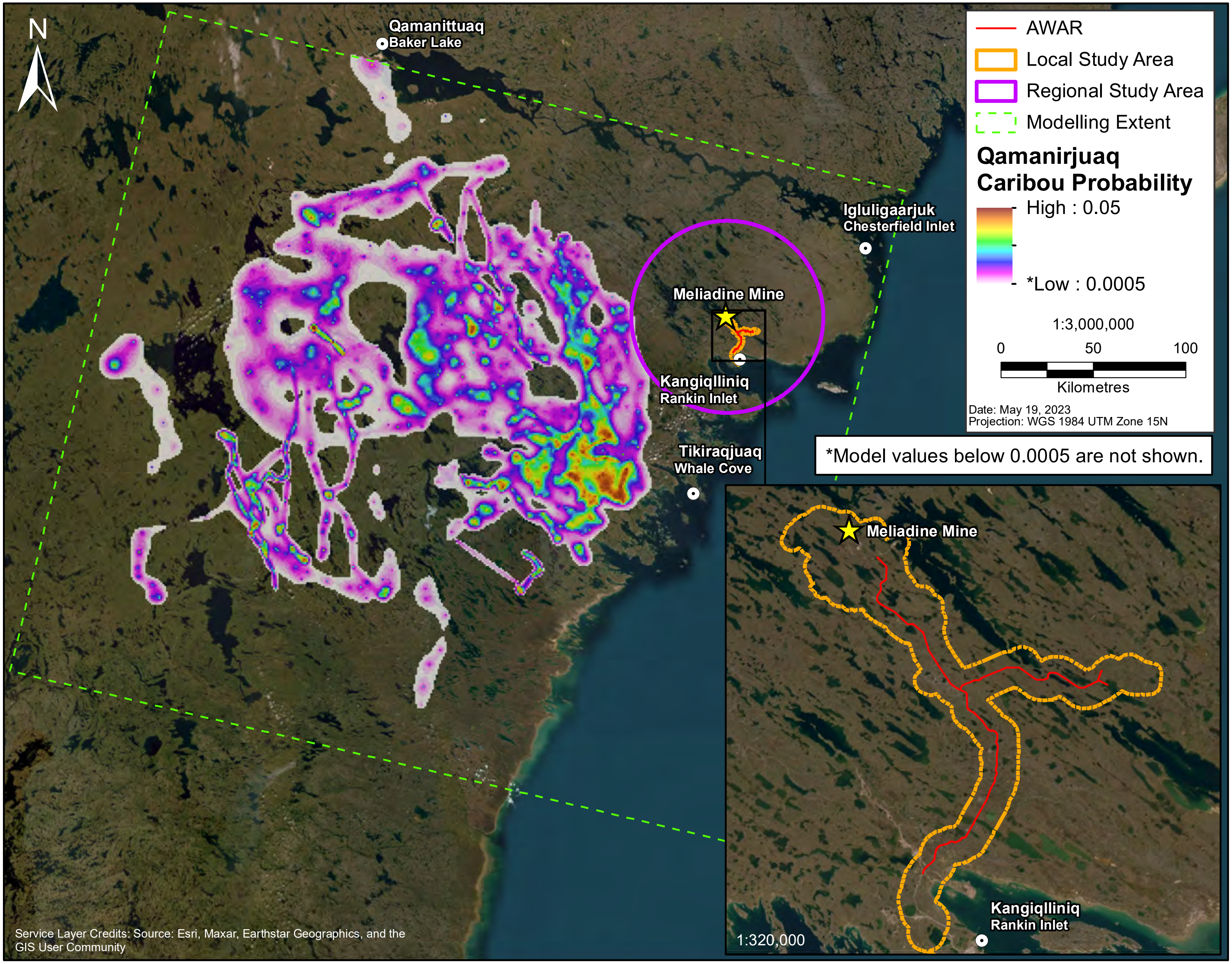

Figure 3.1-4: BBMM for Qamanirjuaq Herd during Post-Calving, Pre-Construction Period (1993-2011)

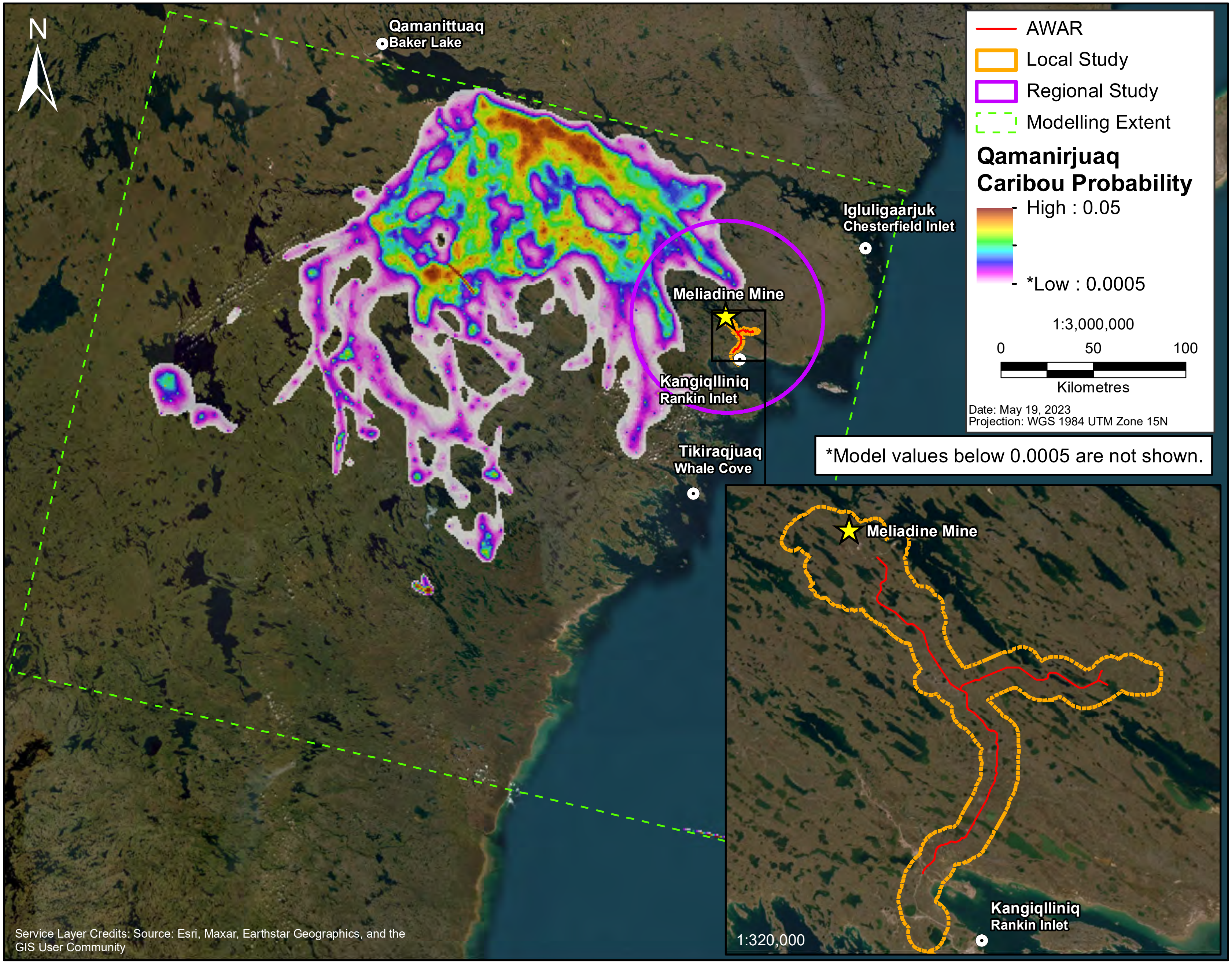

Figure 3.1-5: BBMM for Qamanirjuaq Herd during Post-Calving, Advanced Exploration Period (2012-2017)

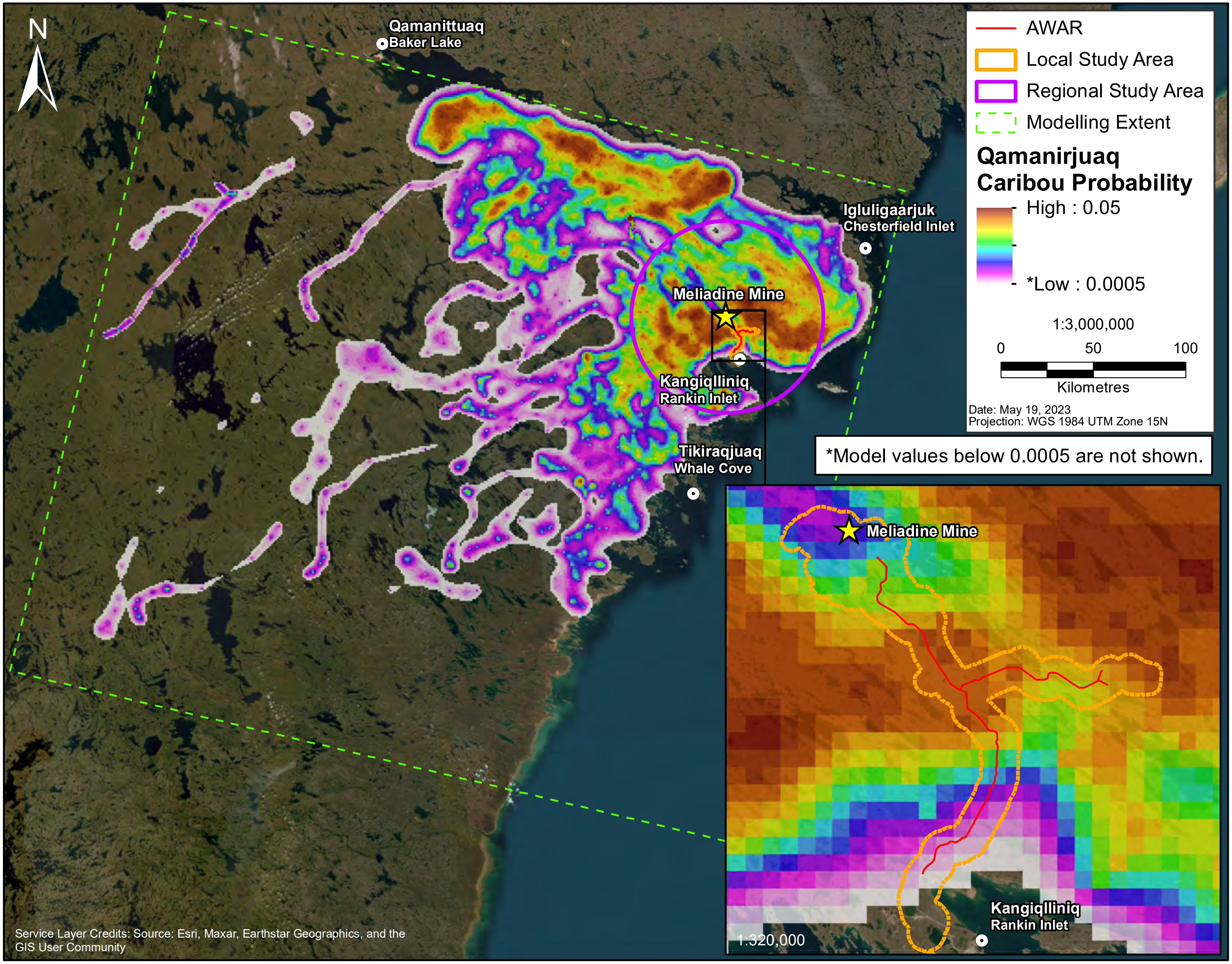

Figure 3.1-6: BBMM for Qamanirjuaq Herd during Post-Calving, Construction and Operation Period (2018-2022)

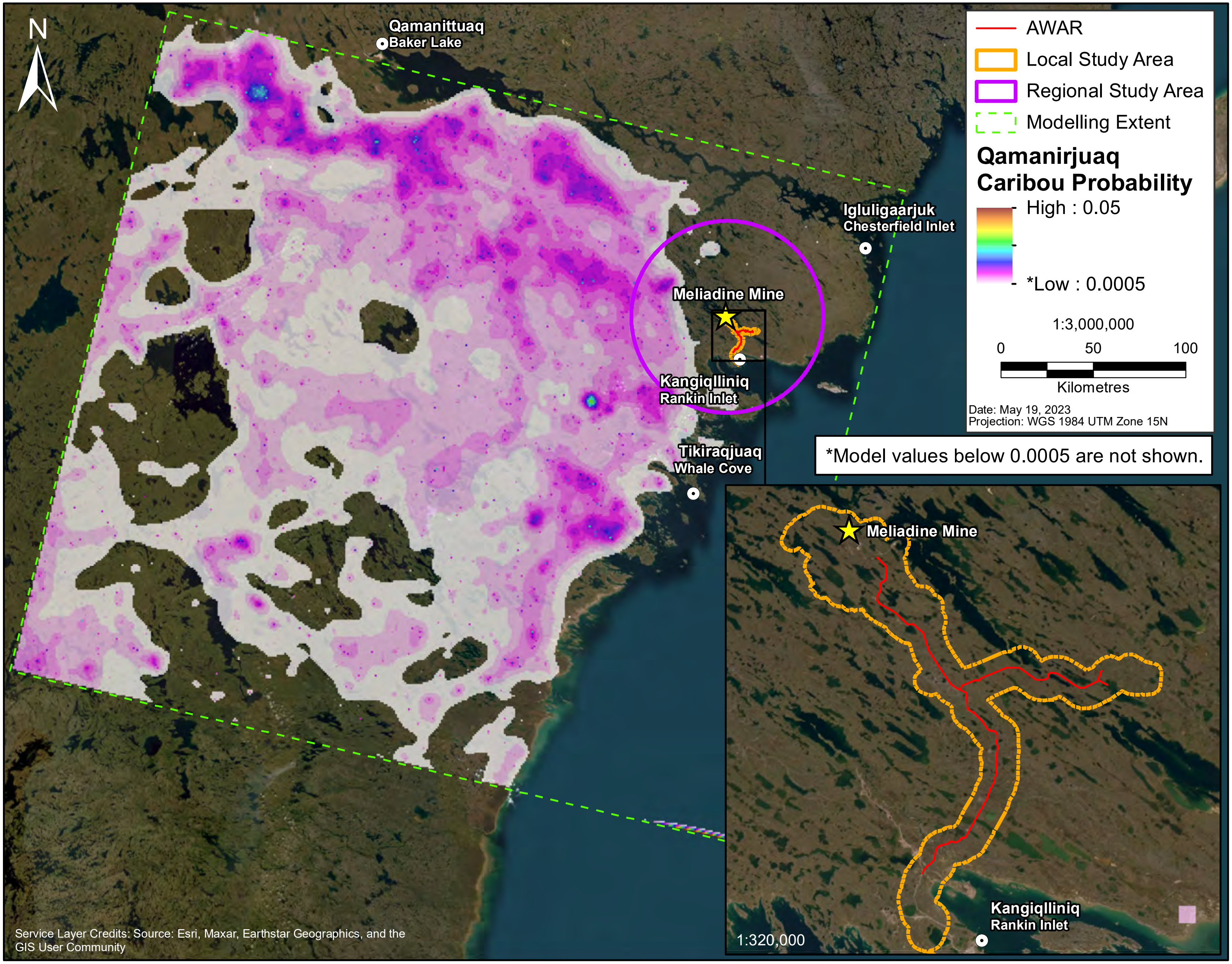

Figure 3.1-7: BBMM for Qamanirjuaq Herd during Summer, Pre-Construction Period (1993-2011)

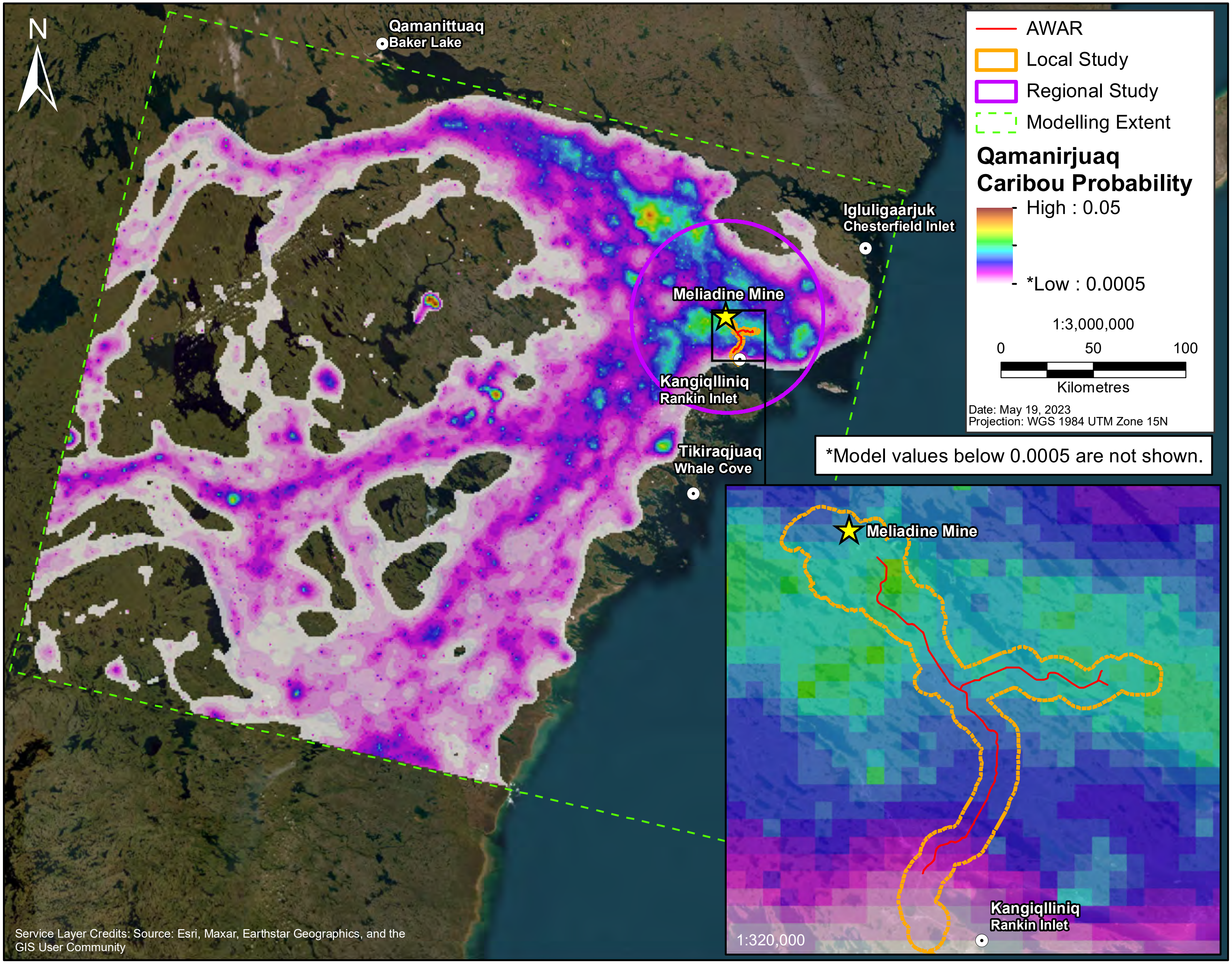

Figure 3.1-8: BBMM for Qamanirjuaq Herd during Summer, Advanced Exploration Period (2012-2017)

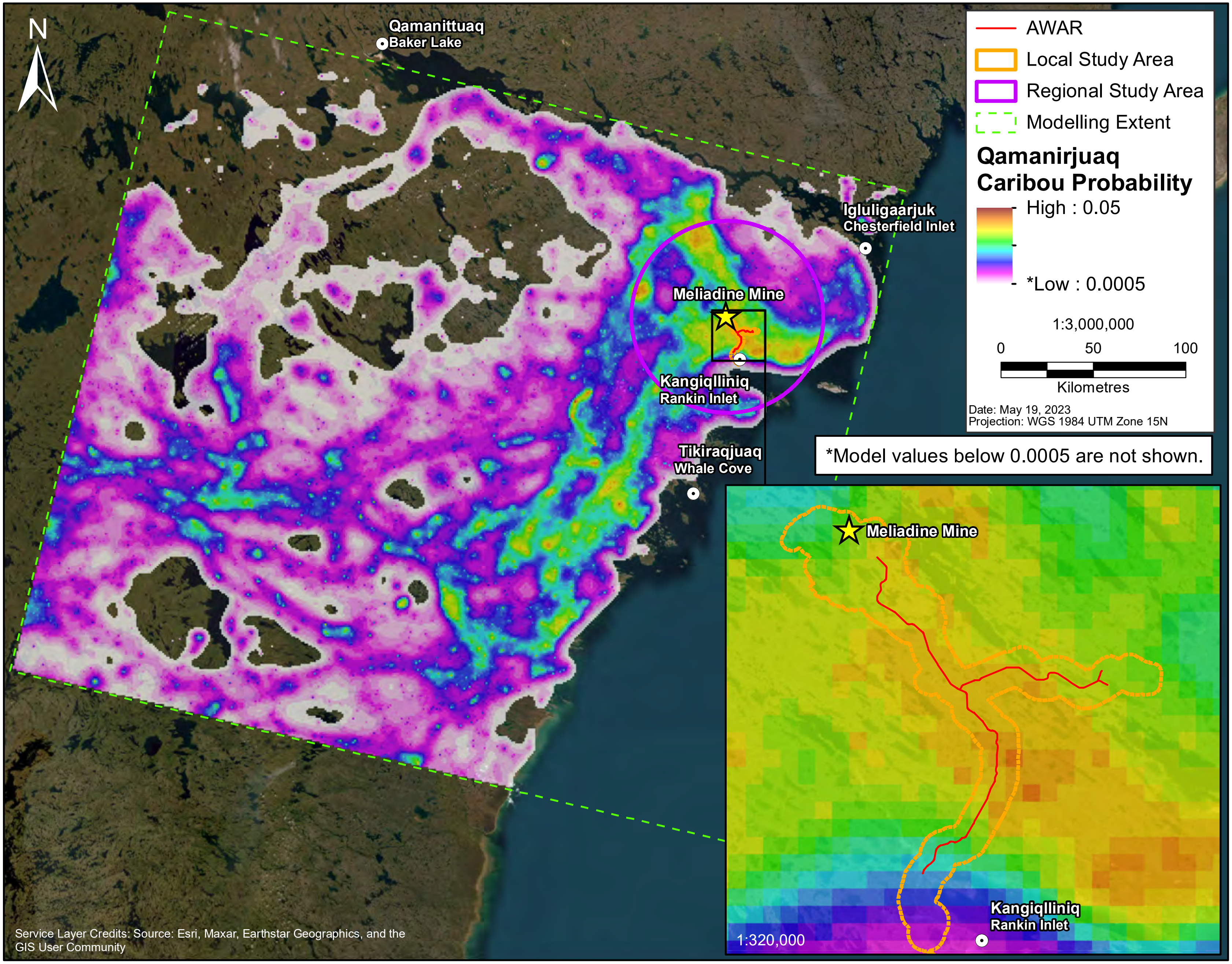

Figure 3.1-9: BBMM for Qamanirjuaq Herd during Summer, Construction and Operation Period (2018-2022)

4. REFERENCES

BQCMB. 2014. Beverly and Qamanirjuaq Caribou Management Plan 2013-2022. Beverly and Qamanirjuaq Caribou Management Board, Stonewall MB.

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Horne, J. S., E. O. Garton, S. M. Krone, and J. S. Lewis. 2007. Analyzing animal movements using Brownian bridges. Ecology 88:2354-2363.

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