The PAME survey:
Arctic marine and coastal mining - environmental issues

Anders Mosbech

Aarhus University and Danish Centre for Environment and Energy

Arctic Mining Workshop March 21-23, 2023

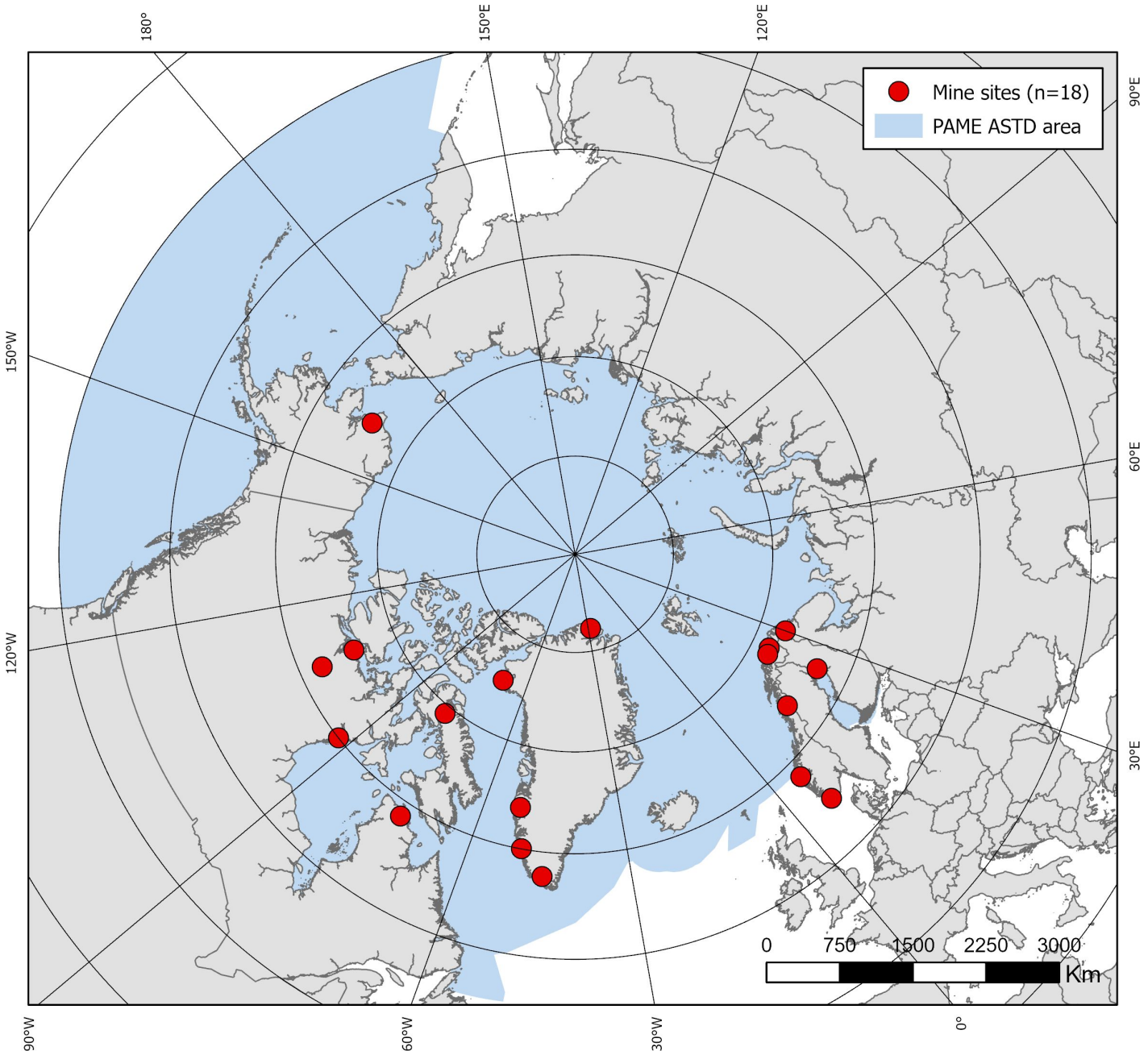
Canada

PINNGORTITALERIFFIK
Greenland Institute of Natural Resources

NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

AARHUS UNIVERSITY
DEPARTMENT OF ECOSCIENCE
DCE - DANISH CENTRE FOR ENVIRONMENT AND ENERGY

Ministry of Environment of Denmark
Environmental Protection Agency



A questionnaire survey

- Includes approved live projects
- Arctic and marine

Project Team

Maureen Copley (co-lead), Janne Fritt-Rasmussen, Libby Chunyk, David Blockley, Kasper L. Johansen

Contributors

Soile Nieminen, Centre for Economic Development, Transport and the Environment for Kainuu (Kainuu ELY Centre), Finland

Siri Anne Haugland Strand, Norwegian Environmental Agency, Norway

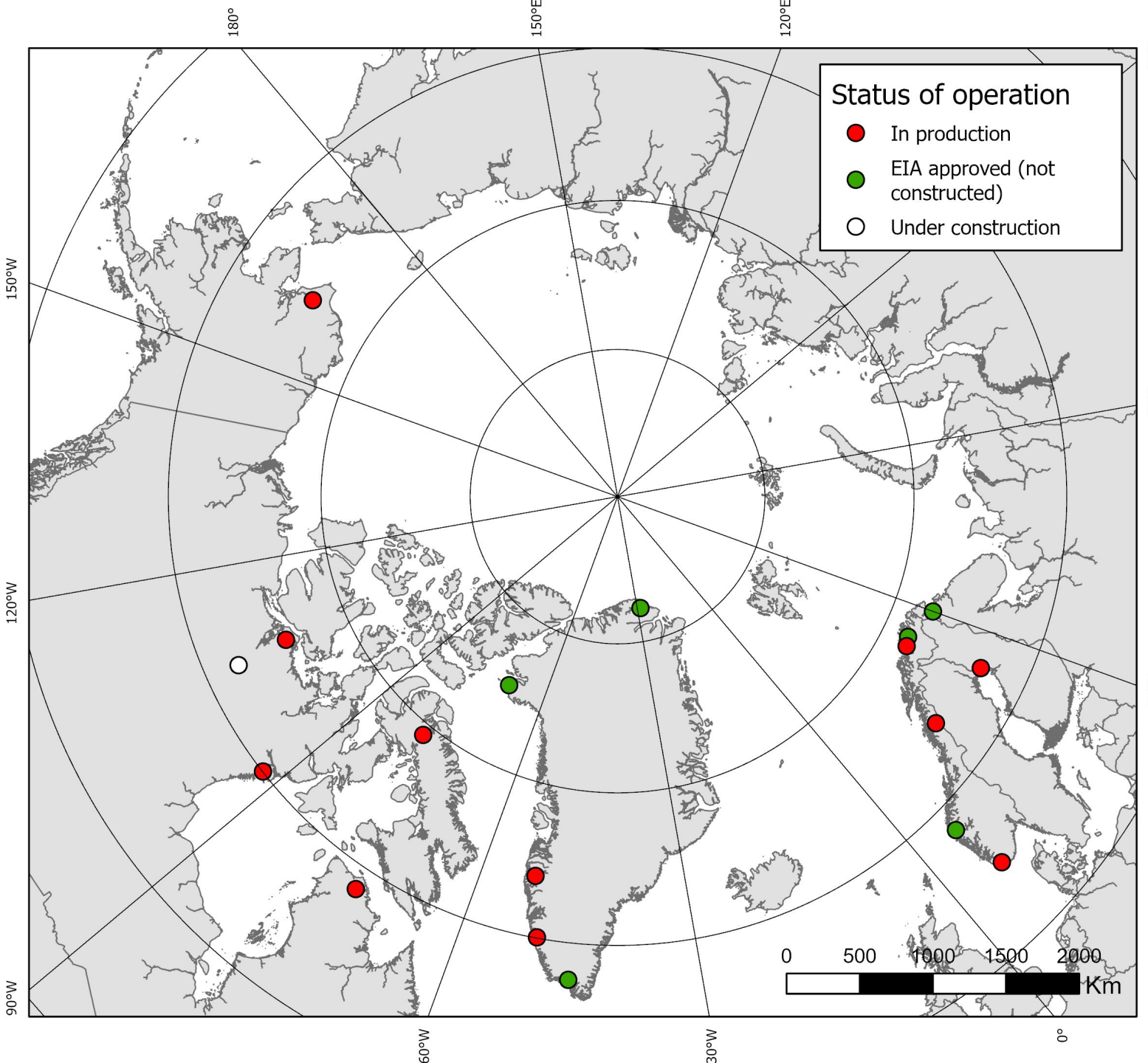
Dennis Thurston, BOEM, USA

And others

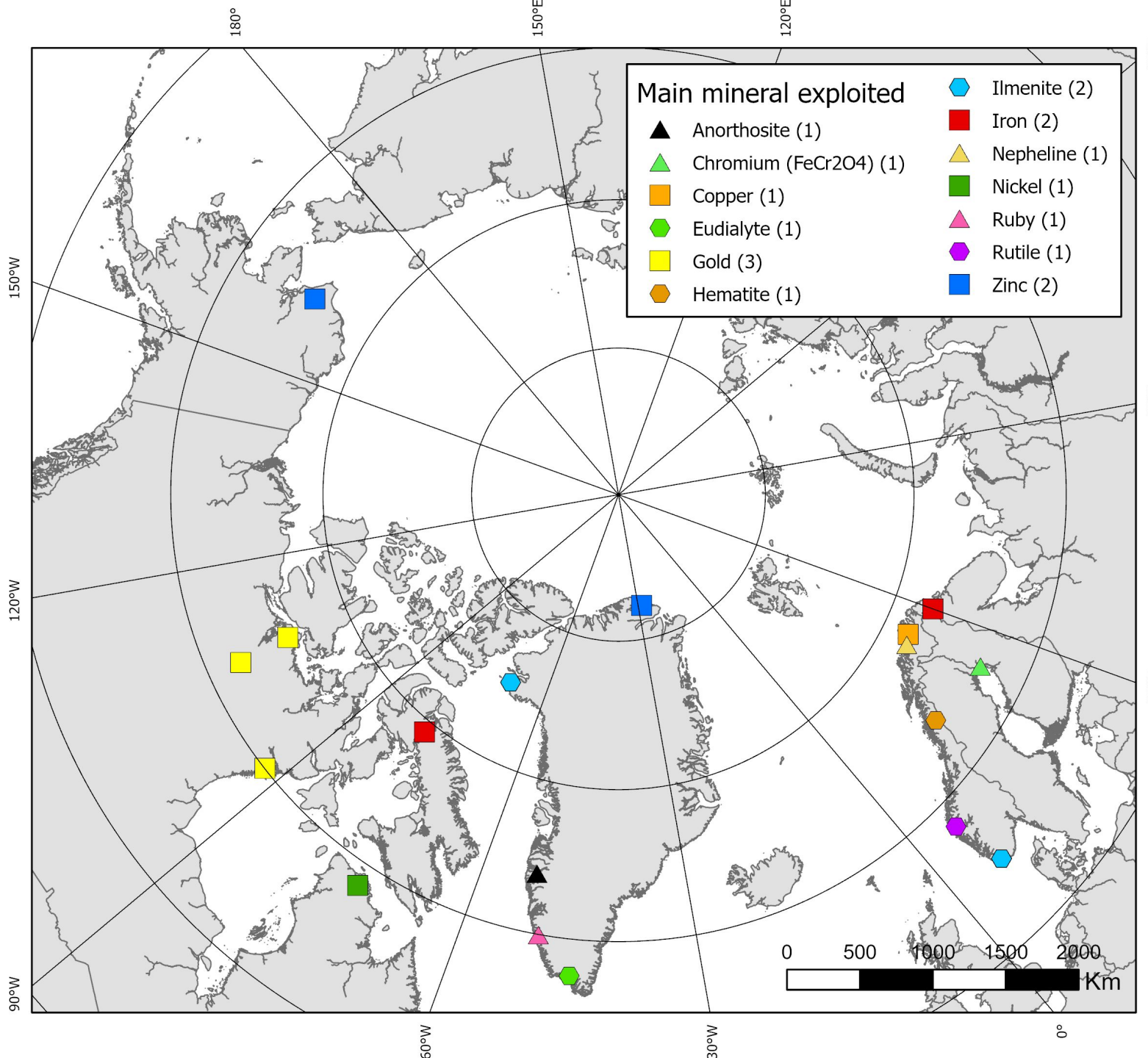
Status of mining operations

11 in production
6 EIA approved
1 under construction

Small scale operations not included e.g. about 60 small scale placer mining oprations in Alaska

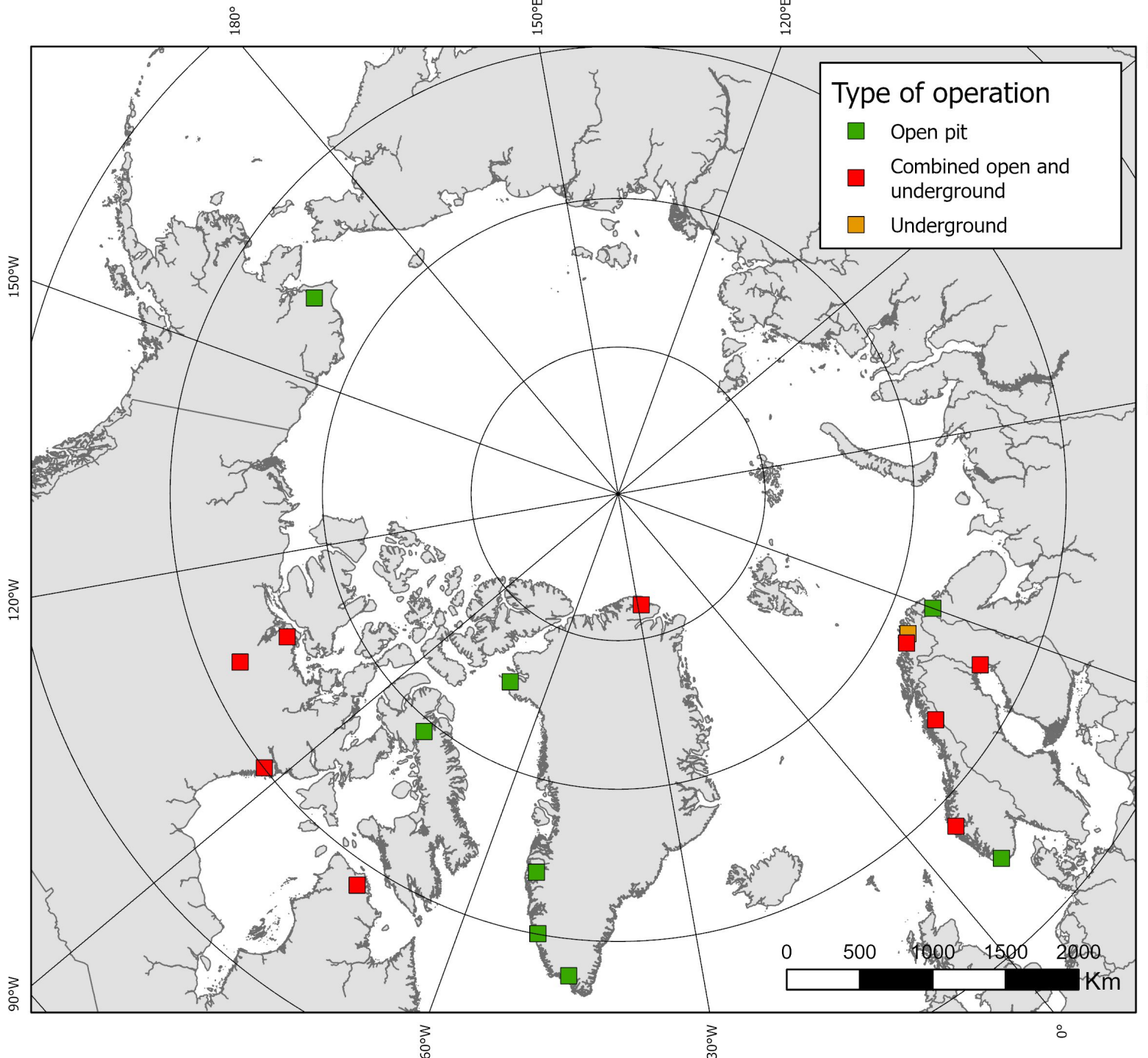


Main minerals exploited

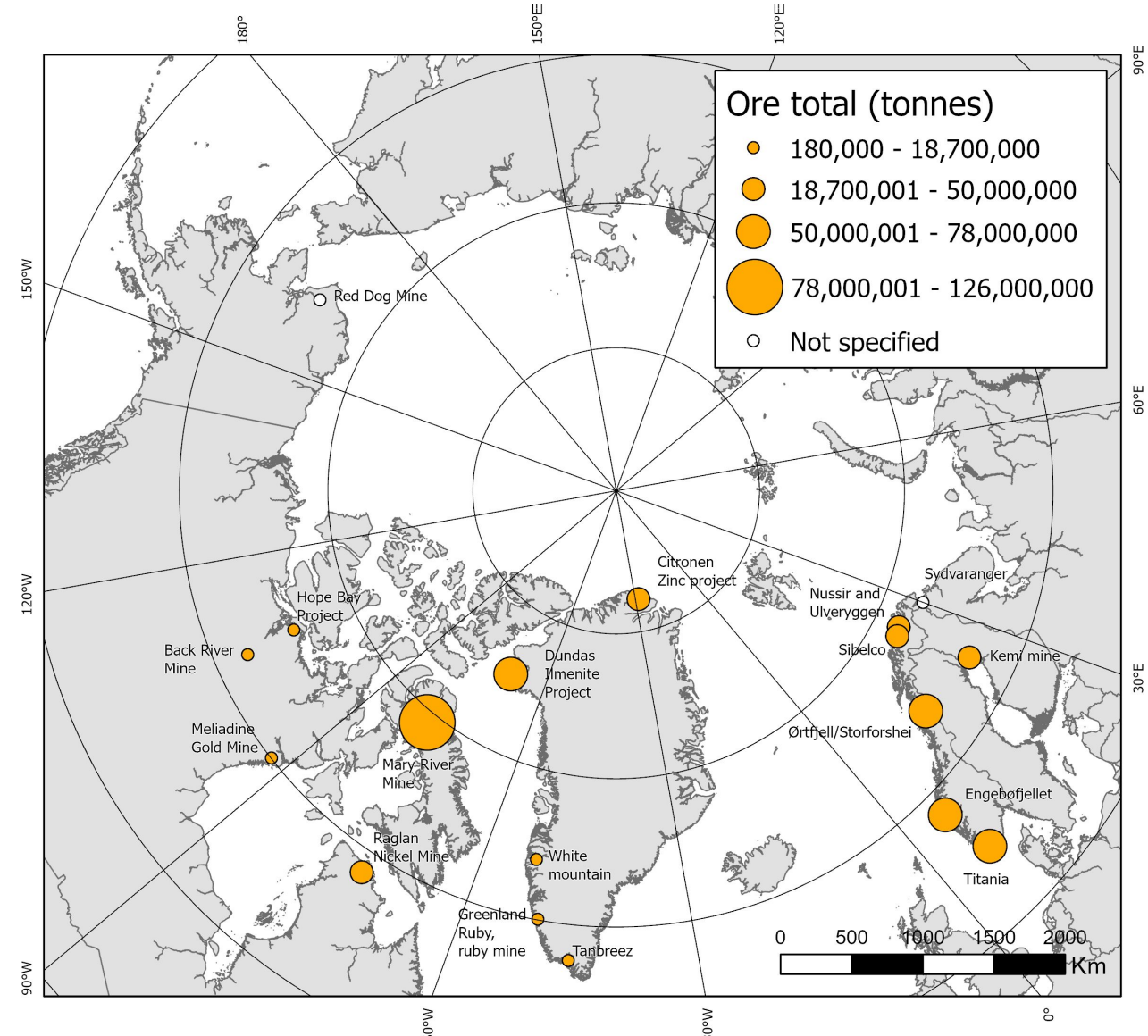


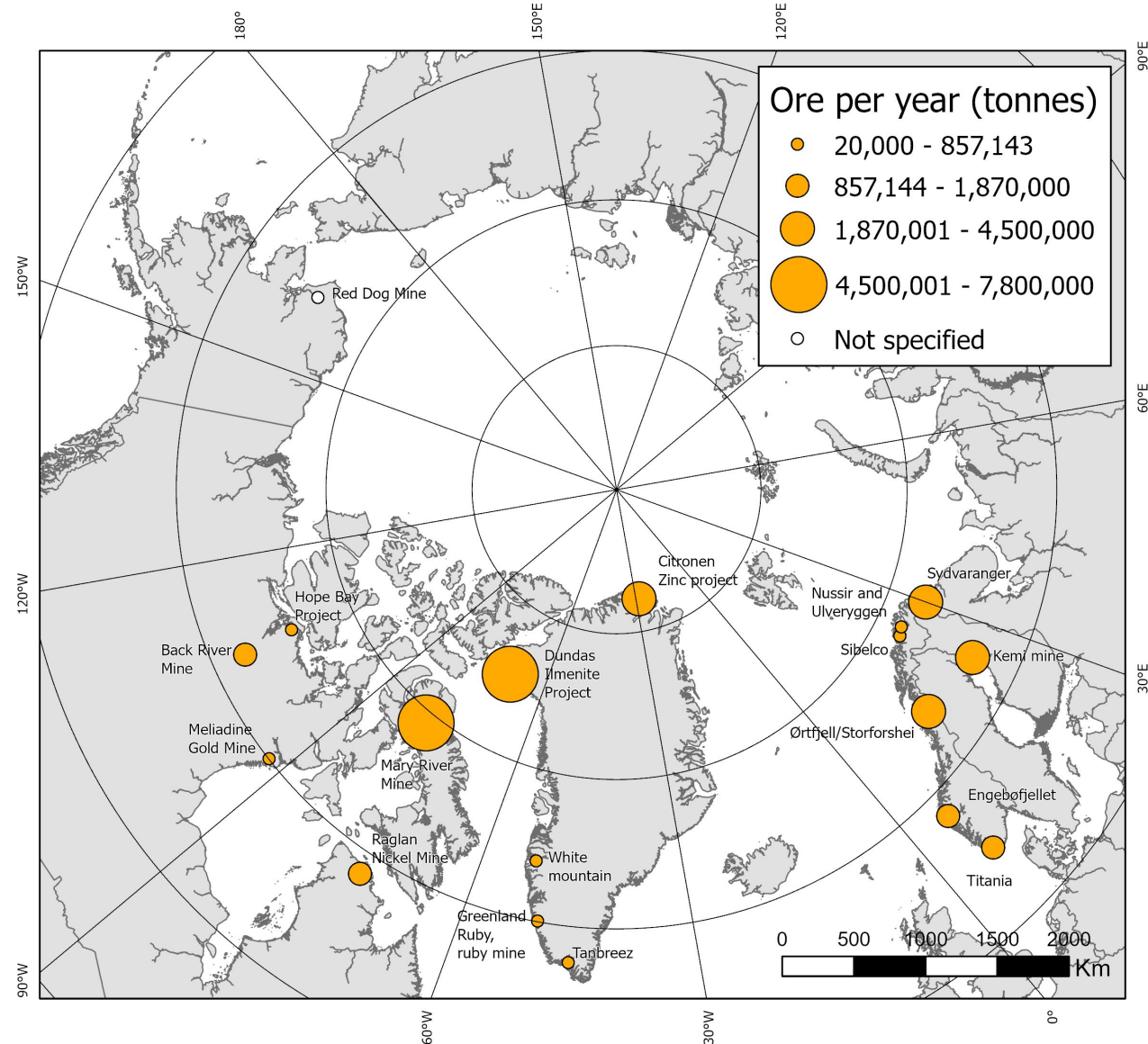
Type of mine operation

8 open pit
9 combined
1 underground

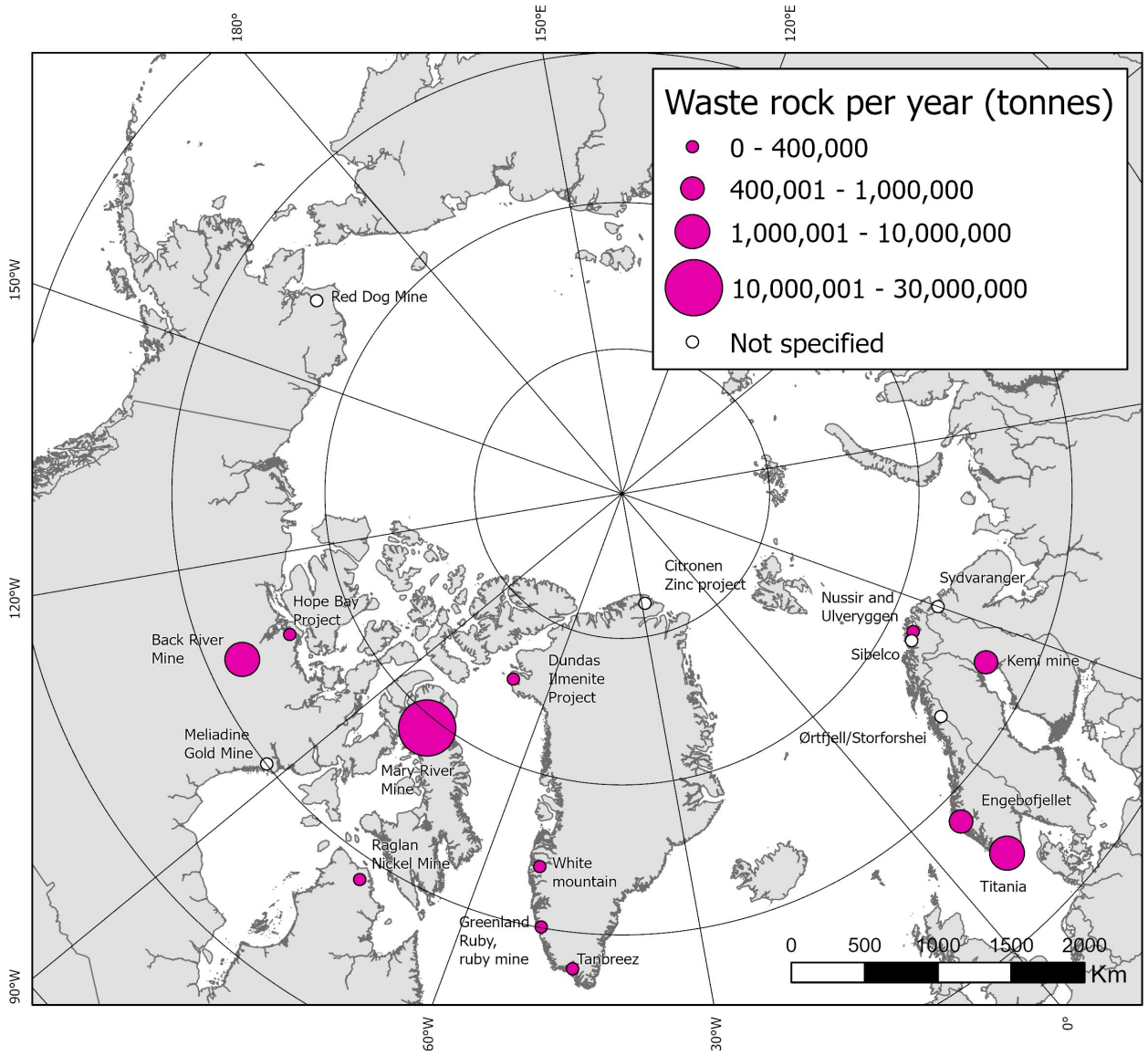


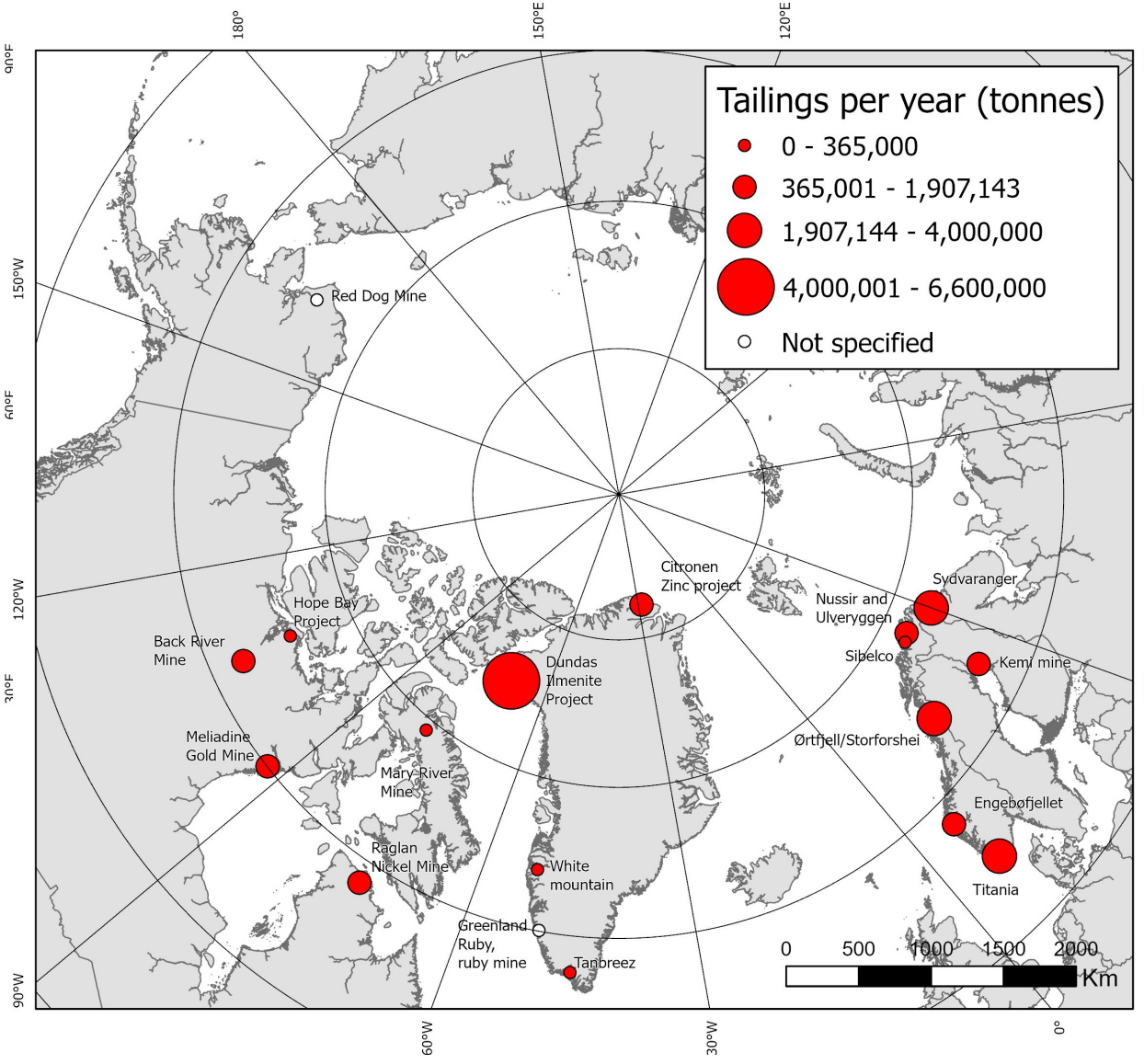
Ore, total and production rate





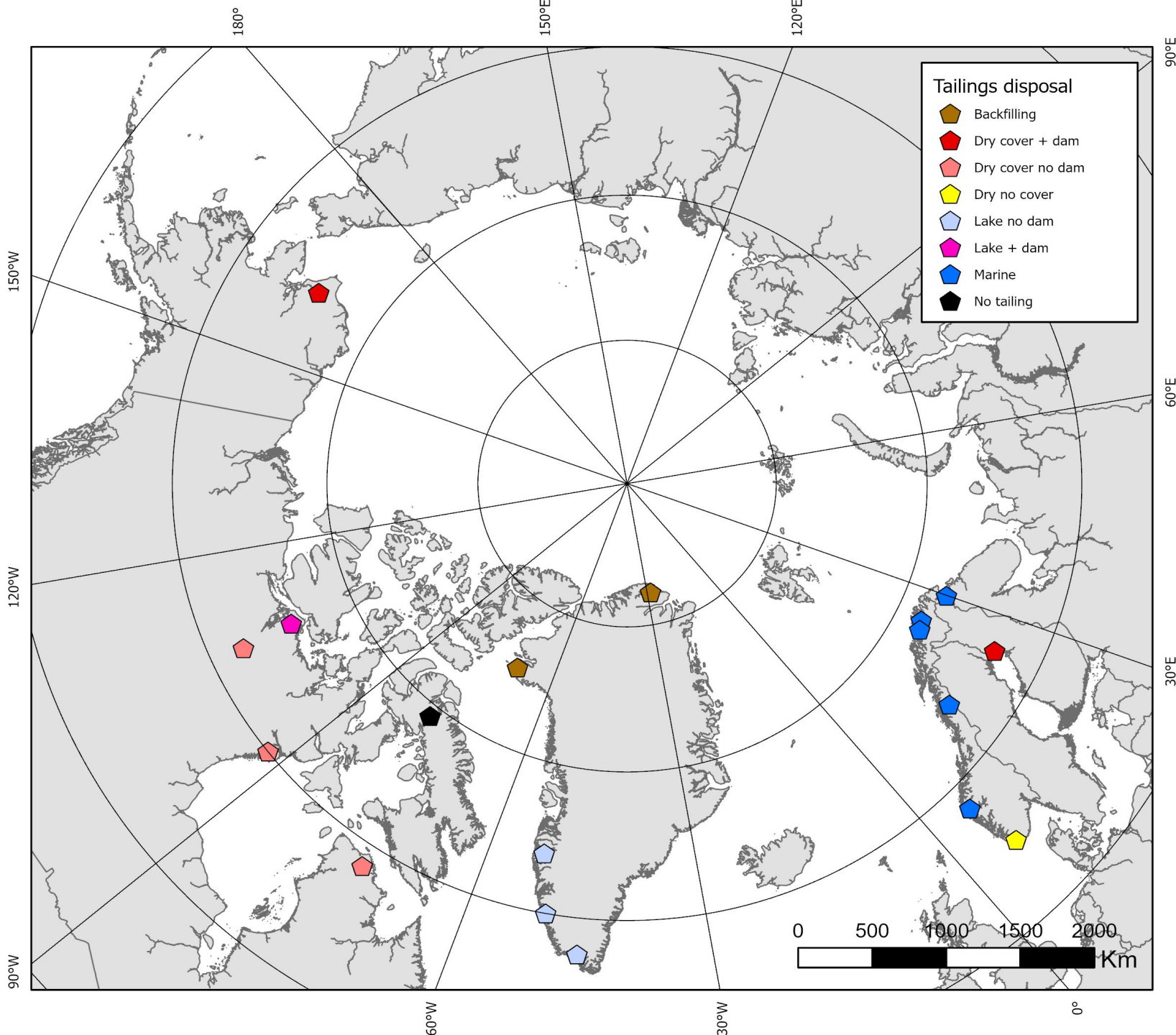
Mining waste produced





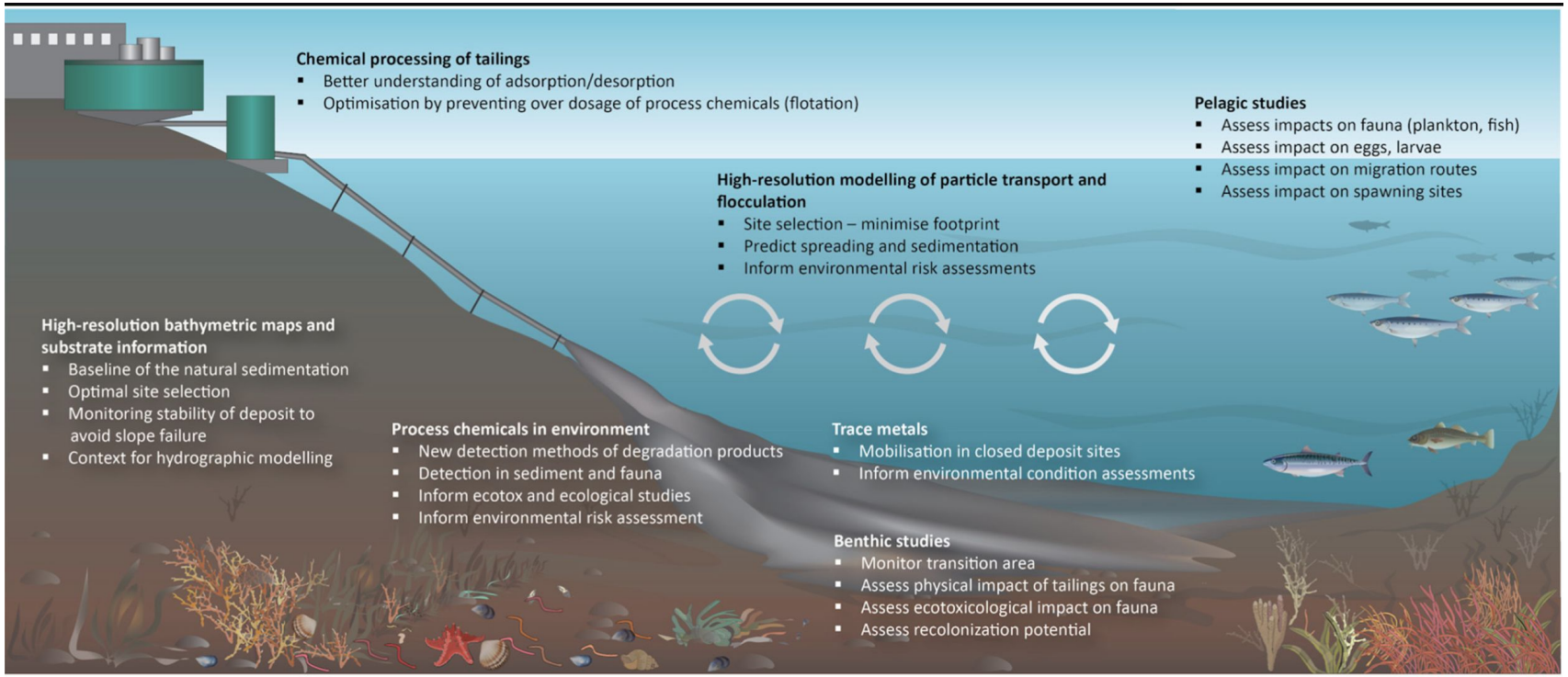
Tailings disposal

Backfilling	2
Dry cover + dam	2
Dry cover no dam	3
Dry no cover	1
Lake no dam	3
Lake + dam	1
Marine	5
No tailing	1



New Research from Norway presented in talk tomorrow

Marine Tailing Disposal: The Norwegian Experience & moderated Q & A. **Hilde Trannum**



Ramirez-Llodra et al. 2022. Marine Pollution Bulletin

New insights into submarine tailing disposal for a reduced environmental footprint: Lessons learnt from Norwegian fjords

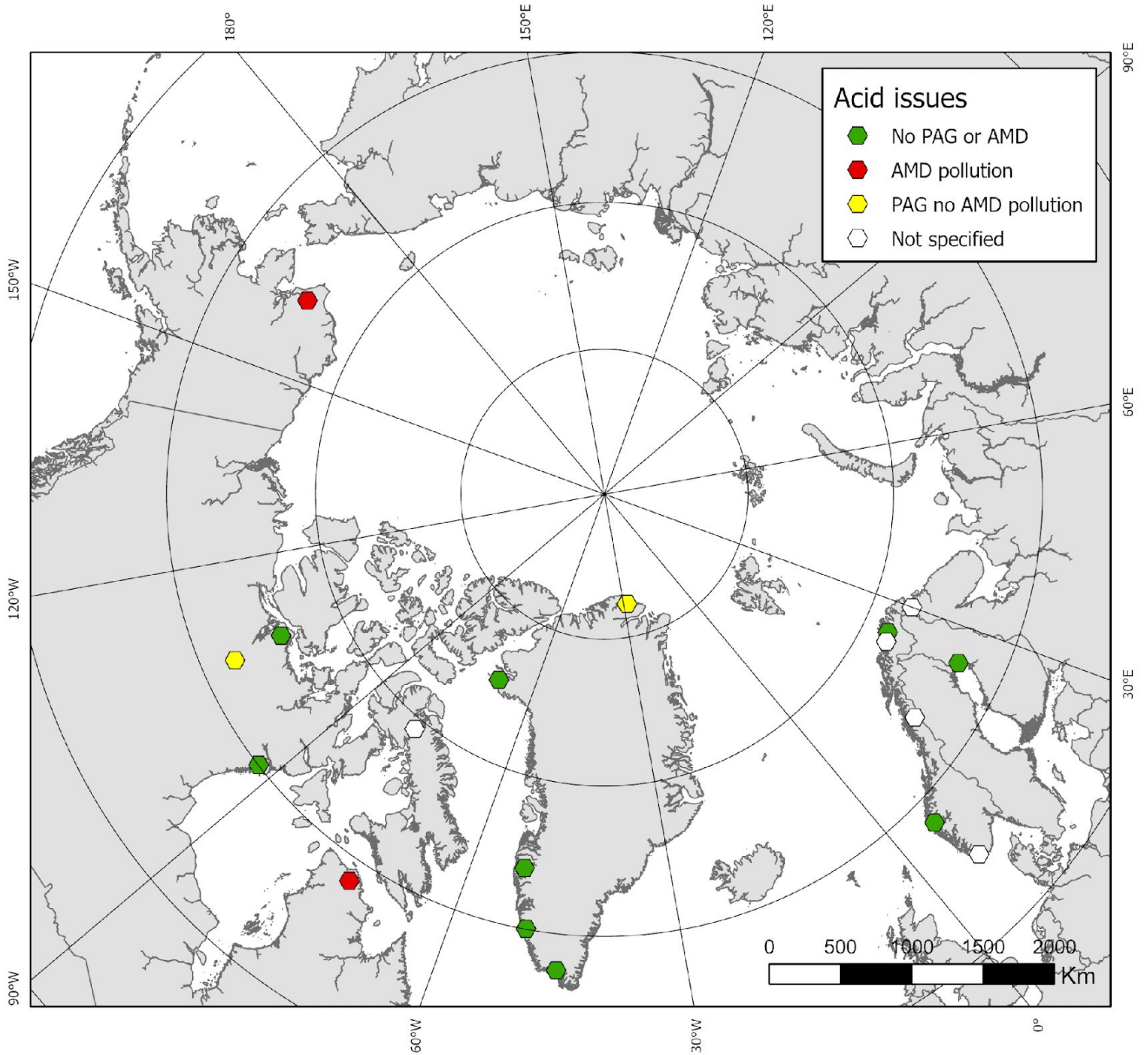
Acid issues

2 PAG: Potentially Acid Generating rock (PAG) is rock with pyrite that when oxidized by surface weathering may form acid which can then leach metals.

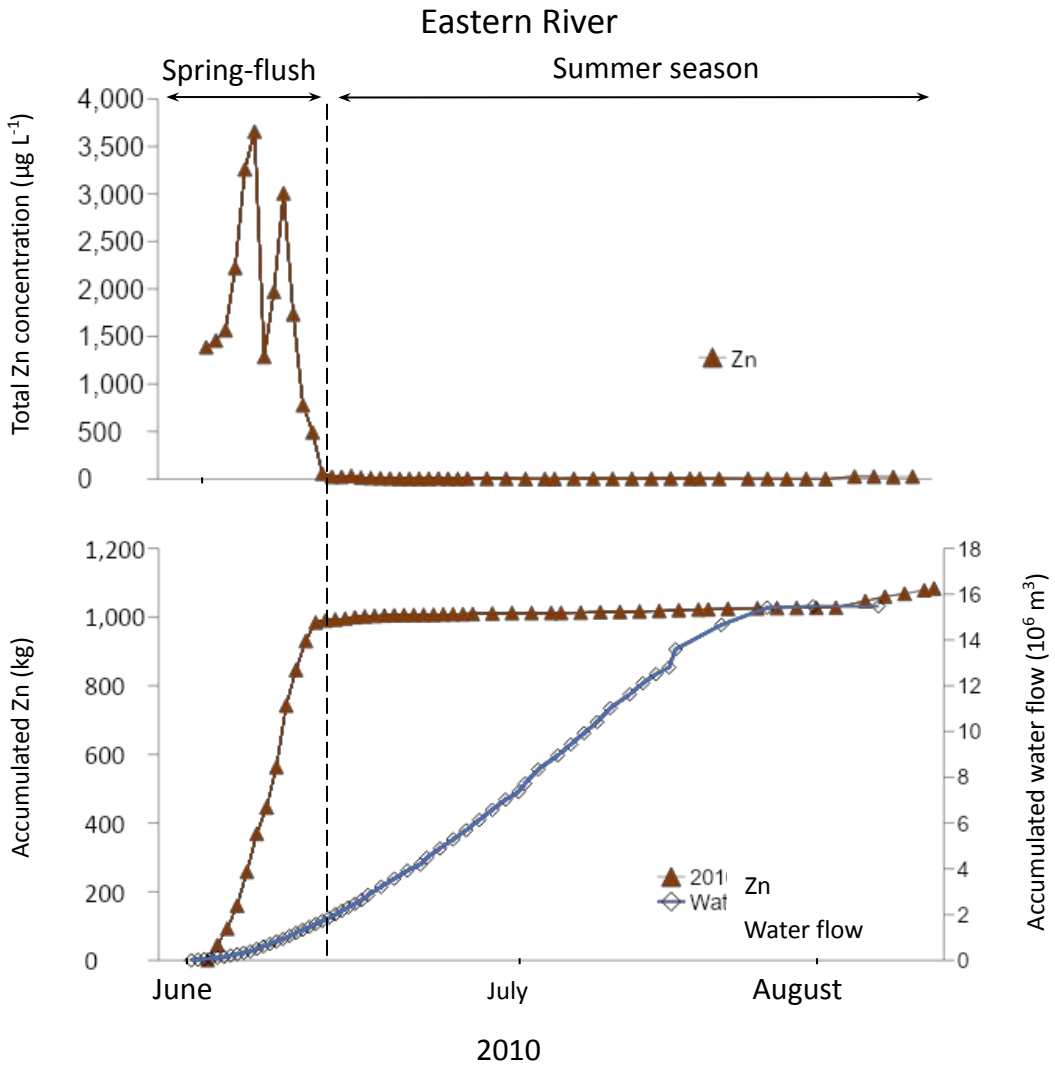
2 AMD: Acid mine drainage (AMD) is drainage/waste water with reduced pH and high levels of dissolved metals.

Acid rock drainage (ARD)
Contaminated neutral drainage (CND).

A



Arctic Conditions with PAG issue
Baseline studies and why it is important (Citronen Fjord)



Søndergaard et al. 2012. Cold Reg Sci Technol 71, 90-94

Example: Raglan Mine – Quebec Research-based PAG management published 2017

AMD: Acid mine drainage
Sulphide nickel deposits in Nunavik,
The mine began production in 1997


ELSEVIER
Journal of Cleaner Production
Volume 162, 20 September 2017, Pages 86-95

Integrated environmental management of pyrrhotite tailings at Raglan Mine: Part 1 challenges of desulphurization process and reactivity prediction

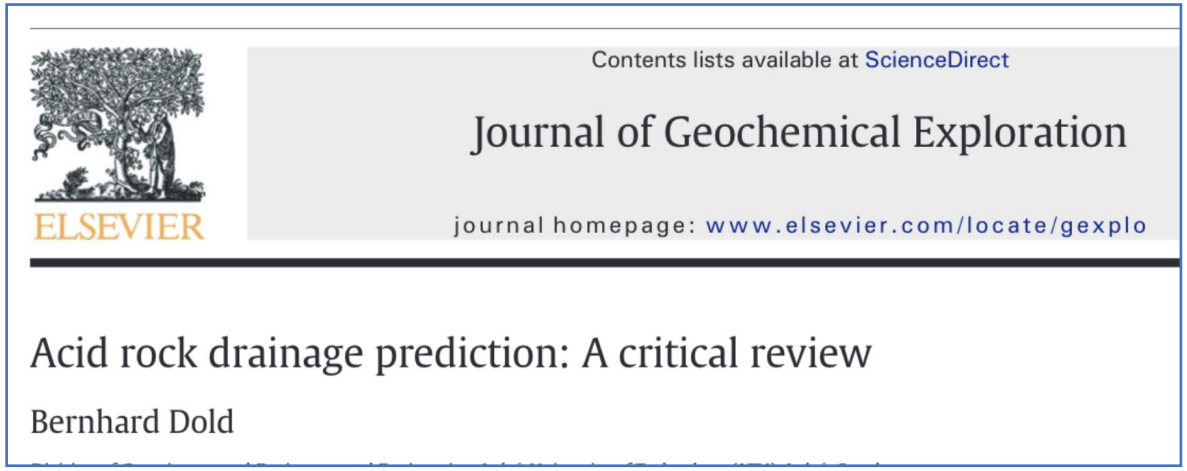
M. Benzaazoua [a], H. Bouzahzah [a], Y. Taha [a], L. Kormos [b], D. Kabombo [a], F. Lessard [a], B. Bussière [a], I. Demers [a], M. Kongolo [a]

Raglan Mine tailings are composed of fine-grained particles with high sulphide content, mainly in the form of pyrrhotite. **The tailings were classified as potentially acid-generating** using acid-base accounting.

Desulphurization using a froth flotation process allowed for the removal of more than >95% of the pyrrhotite occurring within the Raglan Mine tailings.
In terms of environmental behavior, the remaining pyrrhotite in the desulphurized tailings was considered to be non-reactive due to their association with gangue minerals (mainly lizardite).

These tailings did not present significant risk of acid generation and **the leached metals (particularly Ni) are in agreement with the criteria set by Directive 019.**

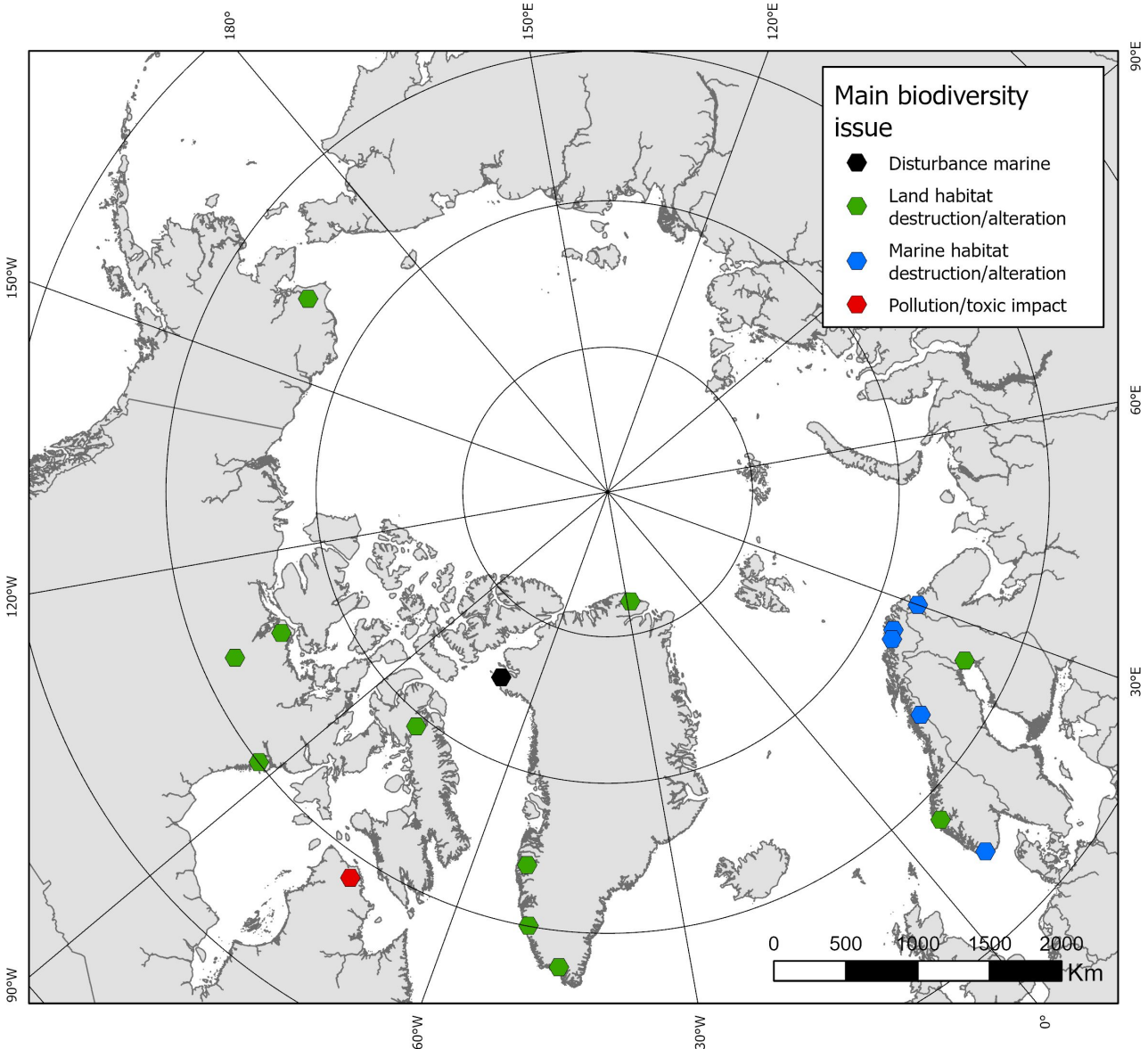
Geochemical testing:
has to be early and integrated



In many modern mining operations, quantitative mineral data is nowadays produced in order to enhance the recovery of the extraction process by **the incorporation of geometallurgical information the use of this very same existing data for Acid Rock Drainage (ARD) prediction** can increase importantly the precision of ARD prediction, often without additional costs and testing. The only requirement is the **interdisciplinary collaboration** between the different divisions and data ex-change in a modern mining operation.

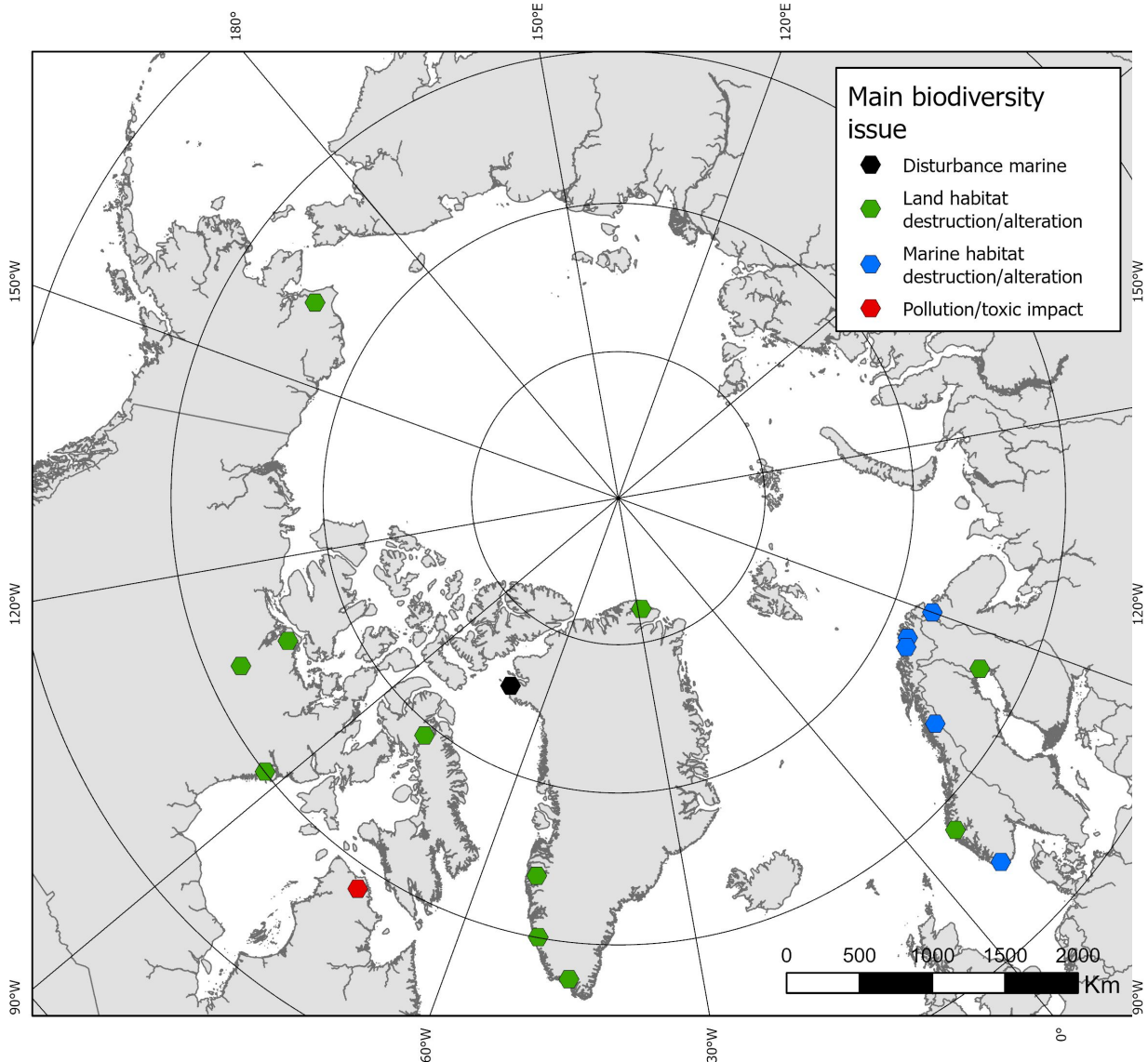
B. Dold 2017. Acid rock drainage prediction: A critical review
J. Geochem. Explor., 172 (2017), pp. 120-132

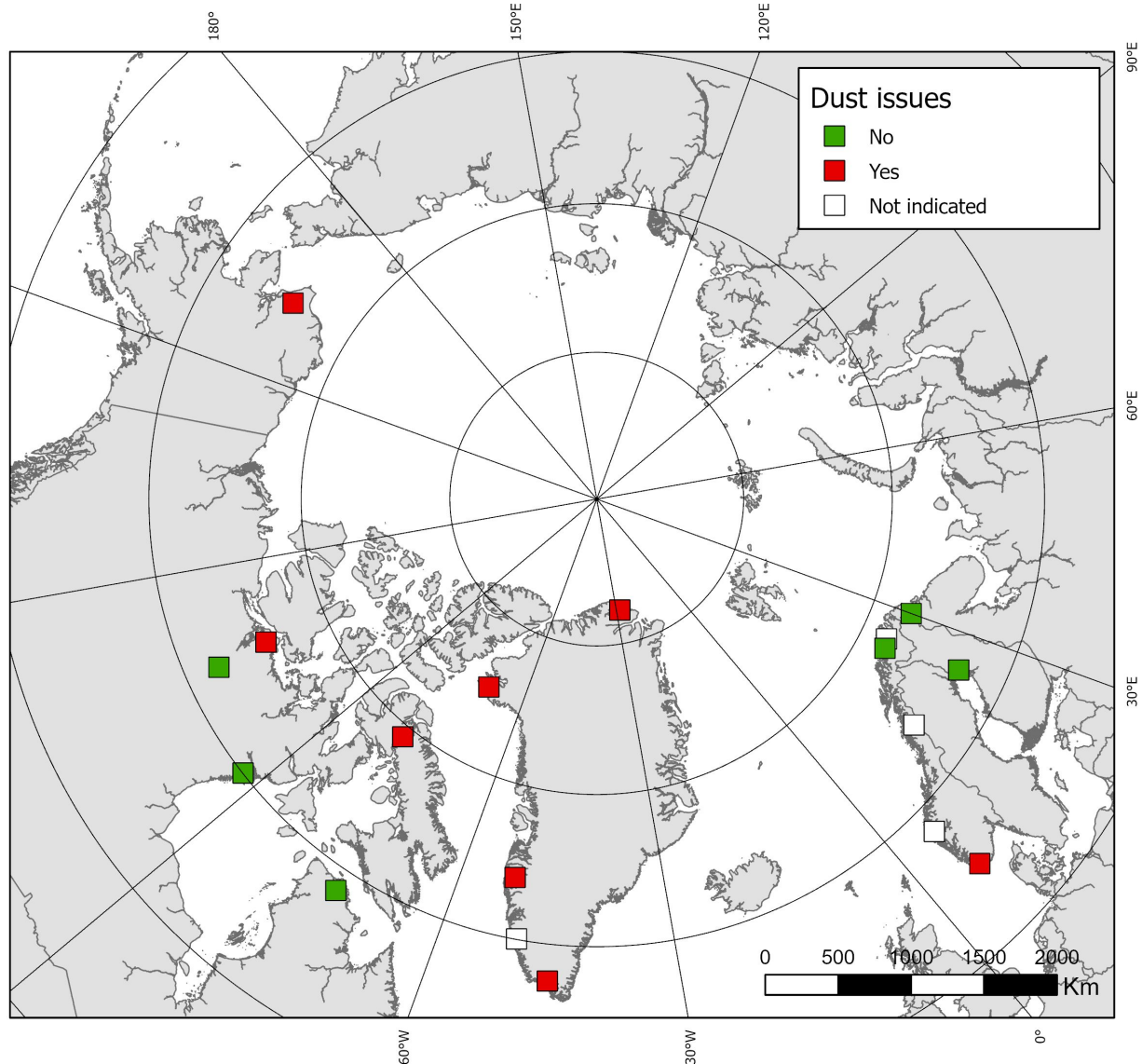
Assessing the footprint – during and after the operation



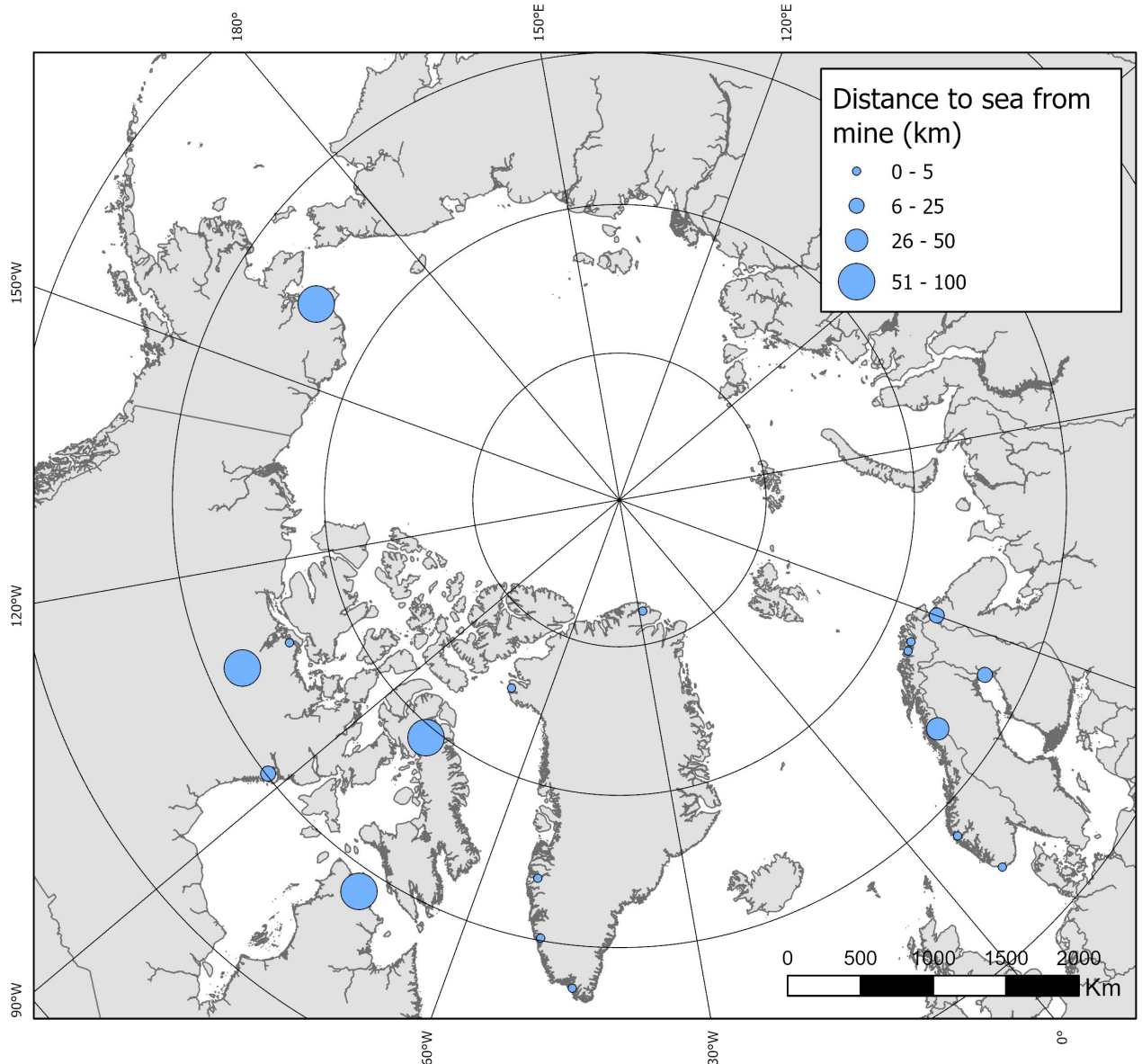
Diverse issues

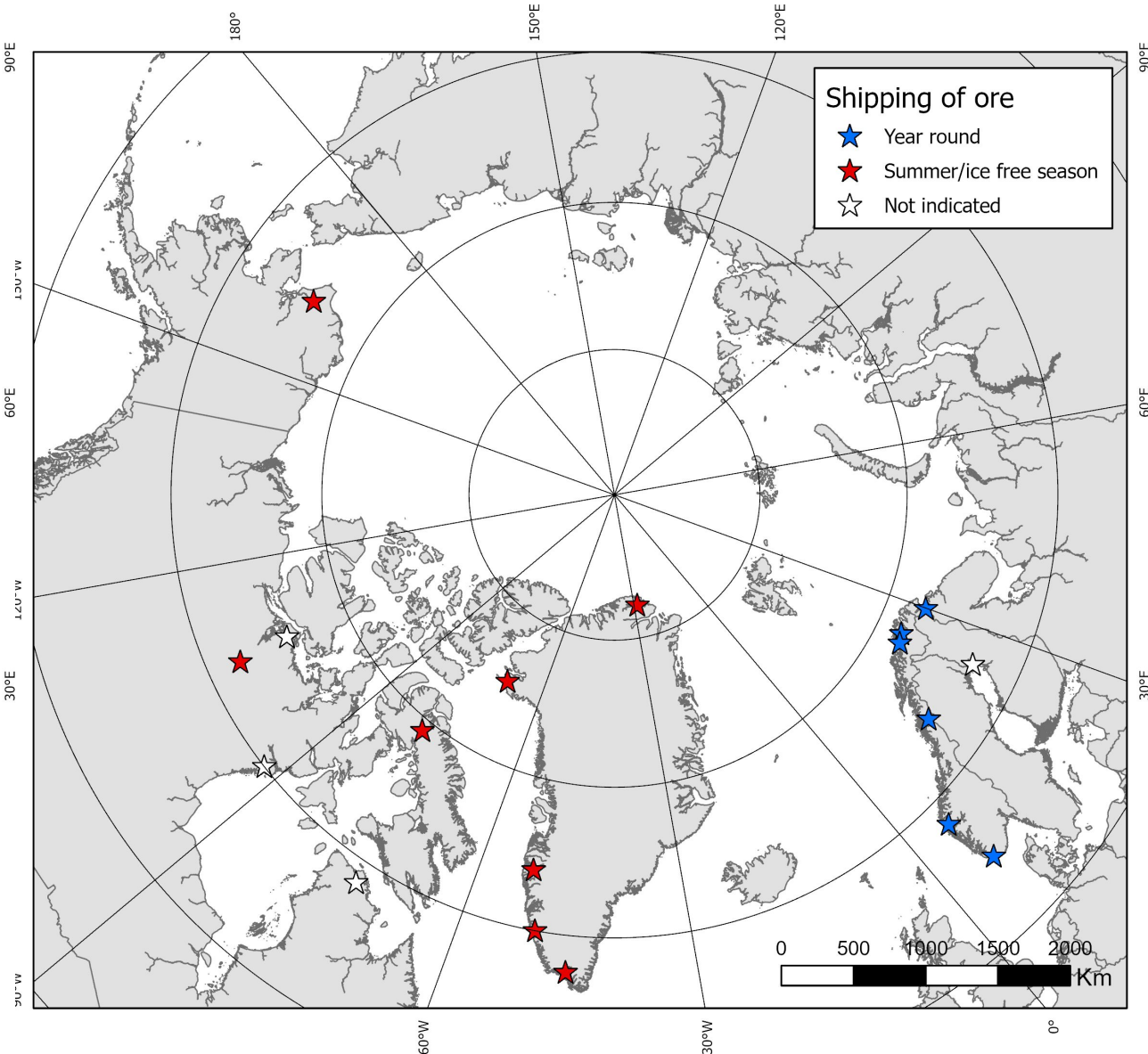
Assessing the footprint – during and after the operation - Dust



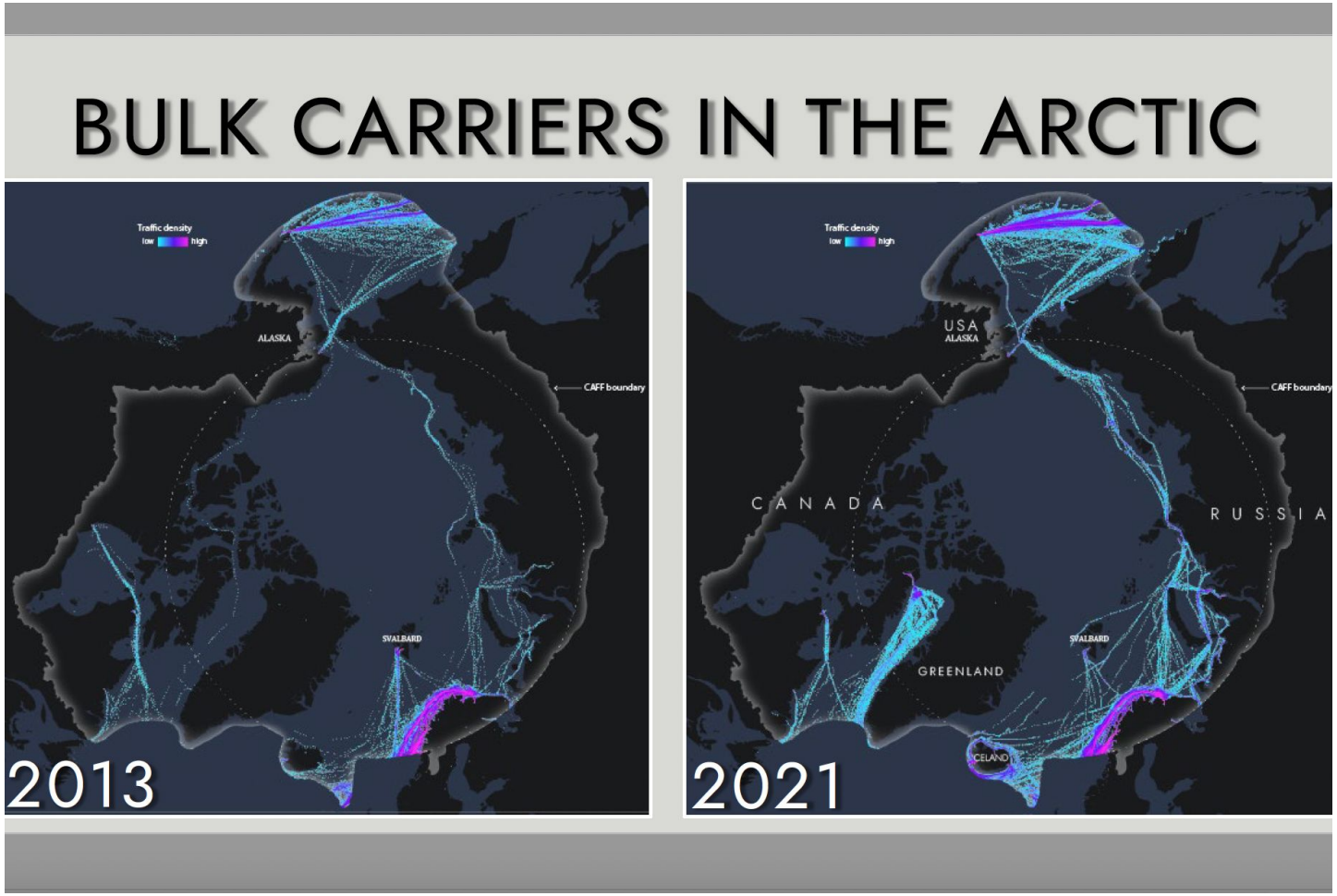


Shipping of ore - a part of the footprint





Shipping of ore - Baffin Bay - and the importance of monitoring



MARY RIVER Iron Mine

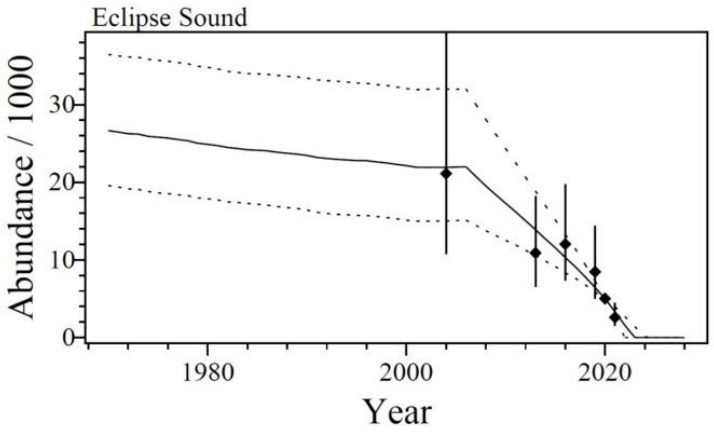
A total of 188 one-way transits of project-related ships occurred during July-October 2020, with icebreakers used early and late in the season.

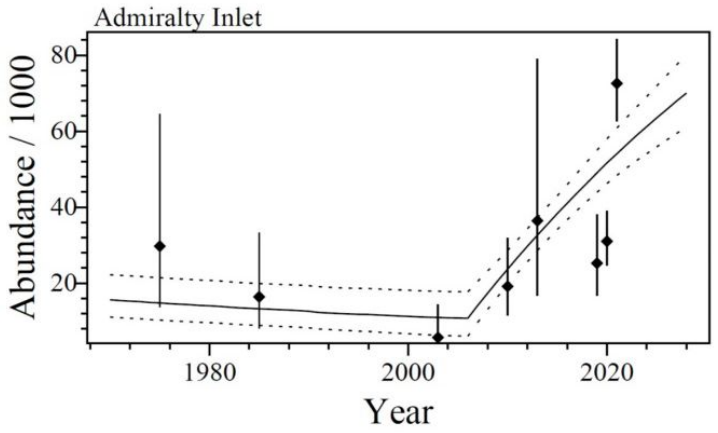
Aerial surveys for marine mammals have been conducted since 2006.

The monitoring showed severe decline in the Narwhal summering population in Eclipse bay

PAME 2022

The importance of regional monitoring - Displacement of Narwhals





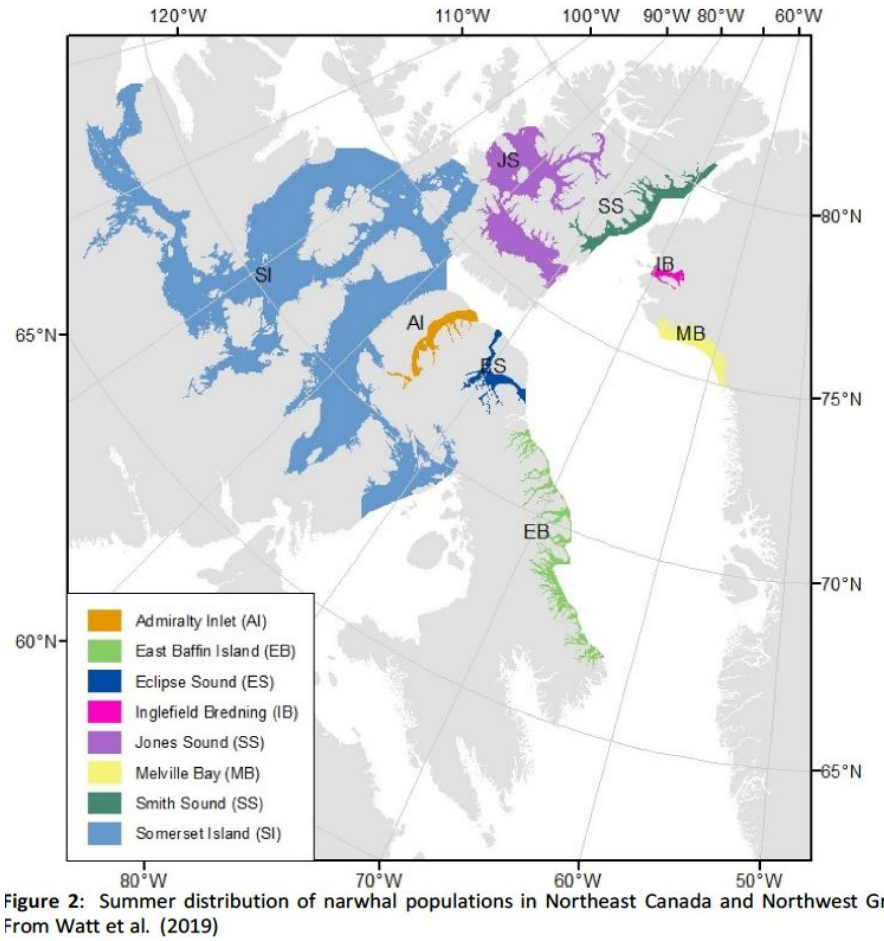


Figure 2: Summer distribution of narwhal populations in Northeast Canada and Northwest Gre
From Watt et al. (2019)

JOINT DISTURBANCE WORKSHOP OF THE NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC. 2022.

Monitoring and Transparency

is evolving

Monitoring and Transparency

an Alaskan example

Alaska Department of Natural Resources
DIVISION OF MINING, LAND AND WATER

COVID Update | Programs | State Land Use | Info | DNR

Home > Mining

Mining Section

- General Information
- Abandoned Mine Lands
- Application for Permits to Mine in Alaska (APMA)
- Coal Regulatory Program
- Large Mines Program
- Mineral Property Management
- Nome Offshore Mining
- Reclamation

Red Dog Mine

Project Description

The Red Dog Mine is an open pit, truck-and-loader operation using grinding and flotation processes to recover zinc and lead. The mine is located in

THE STATE of ALASKA
GOVERNOR MICHAEL J. DUNLEAVY

Departmen
DIVIS

Red Dog Mine Inspection Report

Inspection Date: July 9, 2019 thru July 11, 2019
Weather: Partly Cloudy, Calm winds, 70 to 80 F

Environmental Audits

Red Dog Mine 2021 Environmental Audit PDF (1/25/2022)

Inspection Reports

July 2019 Inspection Report PDF

June 2020 ADF&G Trip Report PDF

July 2020 ADF&G Trip Report PDF

August 2020 ADF&G Trip Report PDF

September 2020 ADF&G Trip Report PDF

Monitoring and Transparency

an Alaskan example

Alaska Department of Fish and Game

Search

Home | Fishing | Hunting | Subsistence | Viewing | Education | Species | Habitat | Regulations

Access & Planning | Conservation Areas | Ecosystems | Habitat Permits | Restoration & Enhancement

Habitat

- Habitat Home
- Access & Planning
- Conservation Areas
- Ecosystems
- Habitat Permits
- Maps & GIS
- Restoration & Enhancement

ADF&G Home » Habitat » Habitatresearch

Red Dog Mine Biomonitoring Studies

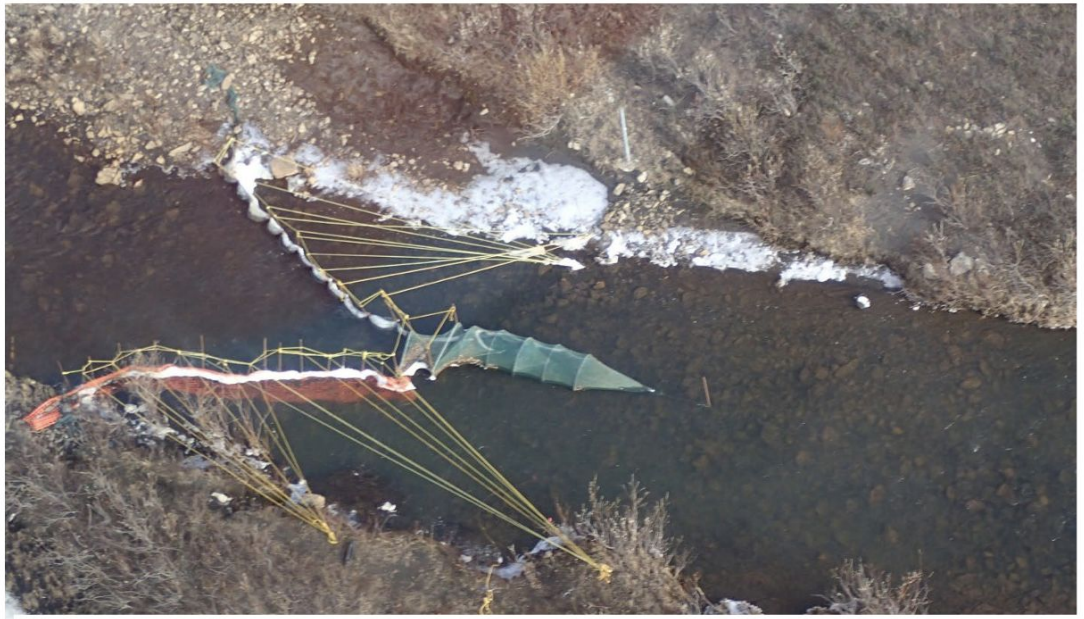
The Red Dog Project is a biomonitoring project required by the EPA permit for the mine's wastewater discharge. Our biomonitoring project includes sampling of streams affected and not affected by the mine. Data on water quality, periphyton (algae), aquatic invertebrates, and fish are components of the study. Monitoring also covers an assessment of the Arctic grayling spawning migration into North Fork Red Dog Creek, metals concentrations in adult and juvenile Dolly Varden, and a population estimate of Arctic grayling in the mine's freshwater reservoir. Yearly surveys are conducted to evaluate the performance of culverts and bridges along the road that connects the mine to the port. From 1999 through 2003, a

Aquatic Biomonitoring at Red Dog Mine, 2021

A requirement under Alaska Pollution Discharge Elimination System Permit No. AK0038652 (Modification #1)

by

Chelsea M. Clawson



May 2022

Alaska Department of Fish and Game **Habitat Section**

Monitoring and Transparency

a Norway example

THE NORWEGIAN PRTR

NORWEGIAN ENVIRONMENT AGENCY

NORWEGIAN | GO TO NORWEGIAN ENVIRONMENT AGENCY | ABOUT THE NORWEGIAN PRTR

Search for a facility

Releases to air and water as well as transfers of waste from different sectors, both aggregated and at facility level.

- Frontpage
- Wastewater treatment plants
- Landfills
- Households
- **Industry**
- Agriculture
- Offshore petroleum industry
- Products
- Transport

Choose county

Choose municipality

Rana Gruber

Show facility on map

Permit and control reports (Norwegian only): Permit, Control report 2004, Control report 2007, Control report 2010, Control report 2013, Control report 2016, Control report 2017, Control report 2019, Control report 2021

Monitoring report for the water body: 2016, 2017, 2018, 2020, 2021, 2022

Authority: Miljødirektoratet

Export to Excel

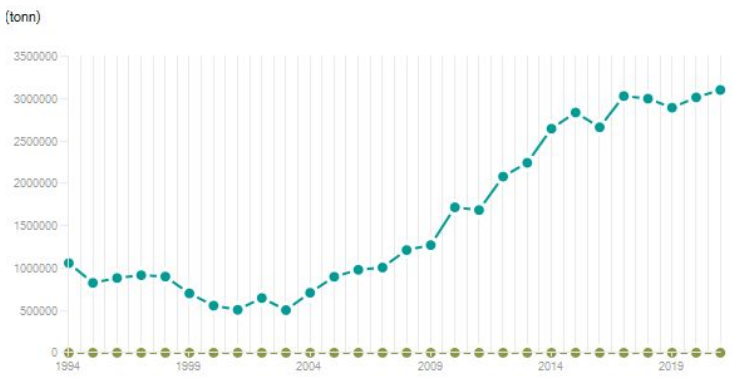
Releases | Transfers of waste | Accidental releases | Energy use | Production volume

Time interval: 1994 – 2021

Compare to...: industry within a geographical area, subsector or a facility.

Releases of Suspended solids (SS) (in tonn per year)

Rana Gruber



View

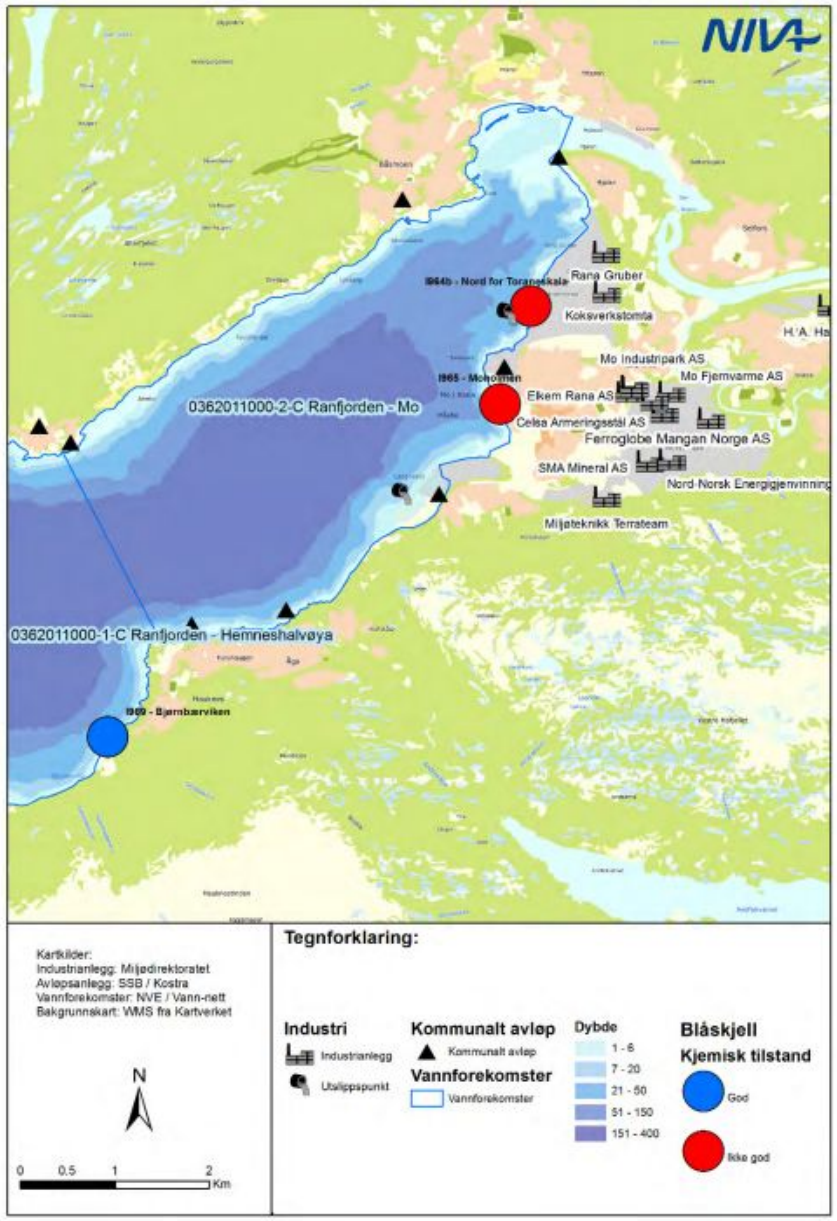
- To air
- To water
- Not reported

Category

- Carbon dioxide (CO2)
- Carbon dioxide fossil (CO2 (F))
- Flow (VANNM)
- Nitrogen oxides (NOx)
- Particulate matter (INSTOV)
- Sulphur dioxide (SO2)
- **Suspended solids (SS)**

3.6 Oversikt over kjemisk tilstand for de undersøkte stasjon Ranfjorden i 2022

Kjemisk tilstand for de undersøkte stasjonene i 2022 vises i **Figur 18**.



Lessons learned

- Background studies, *reflecting year-round conditions, early planning*
  - geochemical leaching tests (and use metallurgical information) and research approach
  - biodiversity, local and regional/population occurrence and sensitivities, integration

- Monitoring, *surprises do occur*
  - monitoring, regional info needed, take account of climate change, feed-back loop
  - new opportunities with technical devices
  - local involvement

- Increasing transparency, *building trust*
  - e.g. online reporting of monitoring results

- Preparing for Ecosystem Based Management in a changing Arctic *?*
  - future management across sectors and involving stakeholders, managing cumulative impacts,
  -shifting baselines - research based solutions

Thank you