Crystalline Rock Site Characterization by Canada's Nuclear Waste Management Organization (NWMO)

Andy Parmenter (and others)
US NWTRB, May 22, 2024

nwmo
NUCLEAR WASTE MANAGEMENT ORGANIZATION
SOCIÉTÉ DE GESTION DES DÉCHETS NUCLÉAIRES

Land acknowledgment

Outline

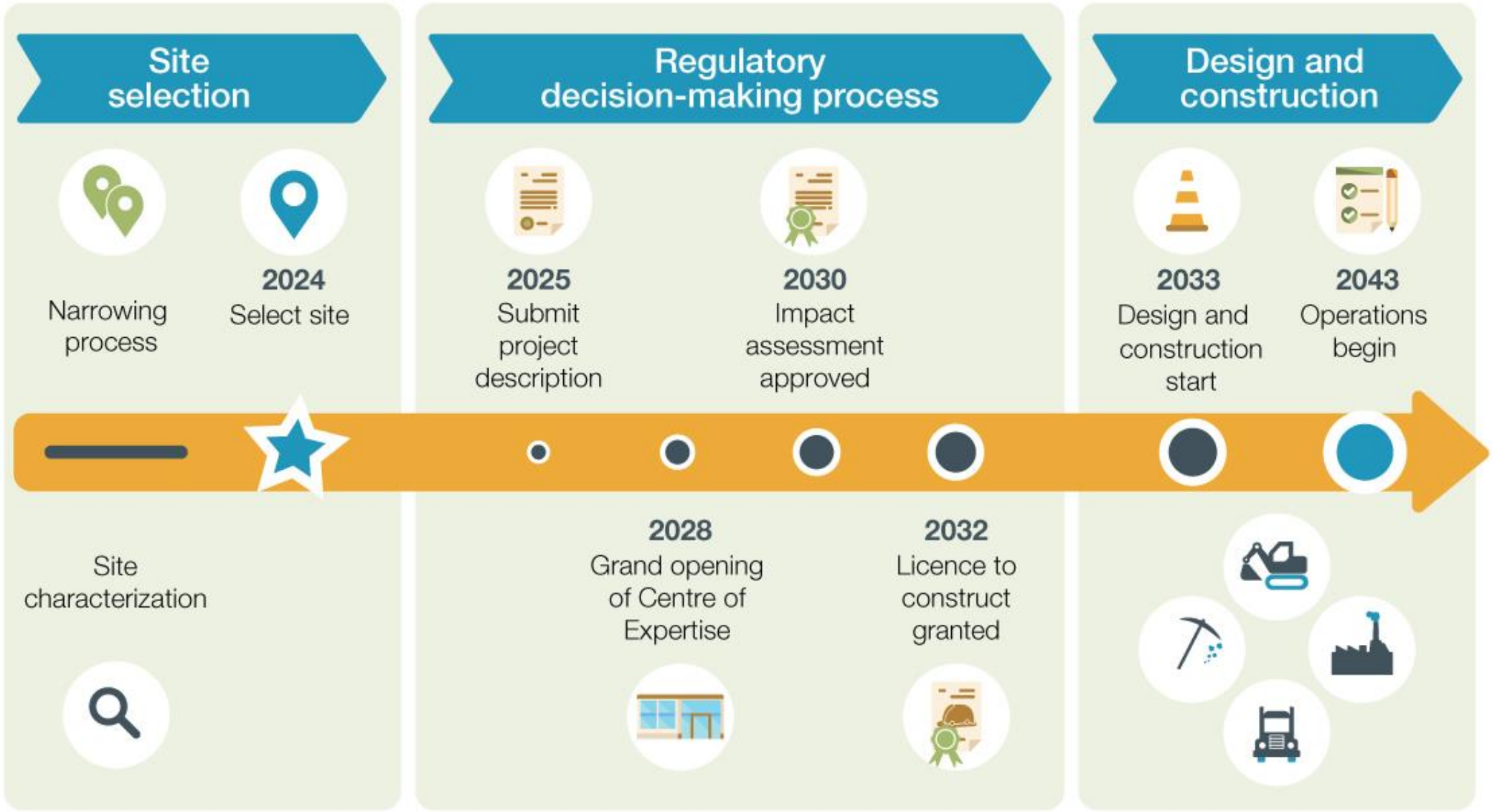
- NWMO: Who we are
- Site Evaluation - A Geoscience perspective
- Crystalline Site Geoscientific Characterization Program
- Lessons Learned

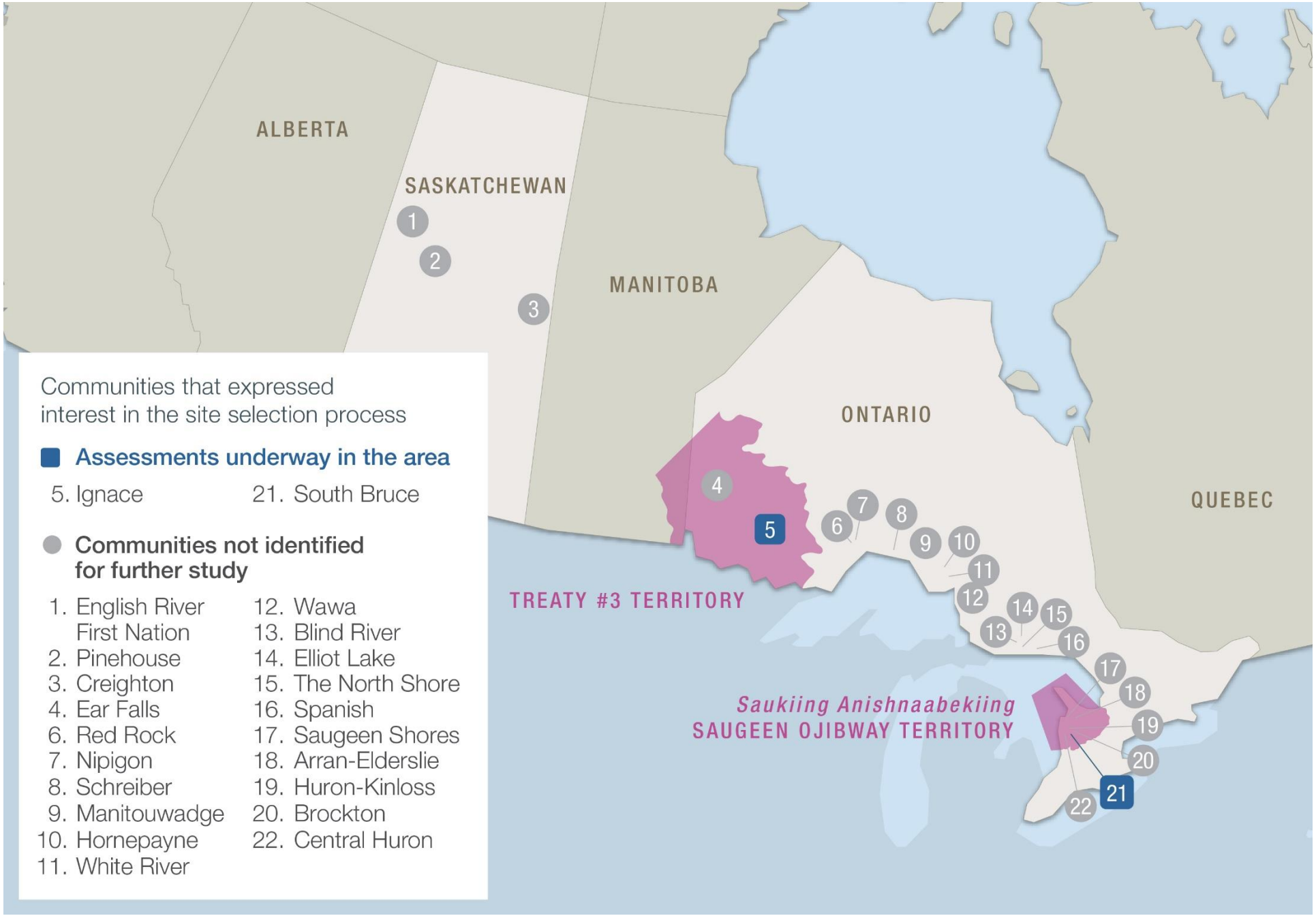
NWMO: Who We Are

- Formed in 2002 as required by *Nuclear Fuel Waste Act*
- Funded by Canada's nuclear energy corporations
- Operates on a not-for-profit basis

Our mission is to develop and implement collaboratively with Canadians, a management approach for the long-term care of Canada's used nuclear fuel that is socially acceptable, technically sound, environmentally responsible, and economically feasible.

Our Planning Timelines

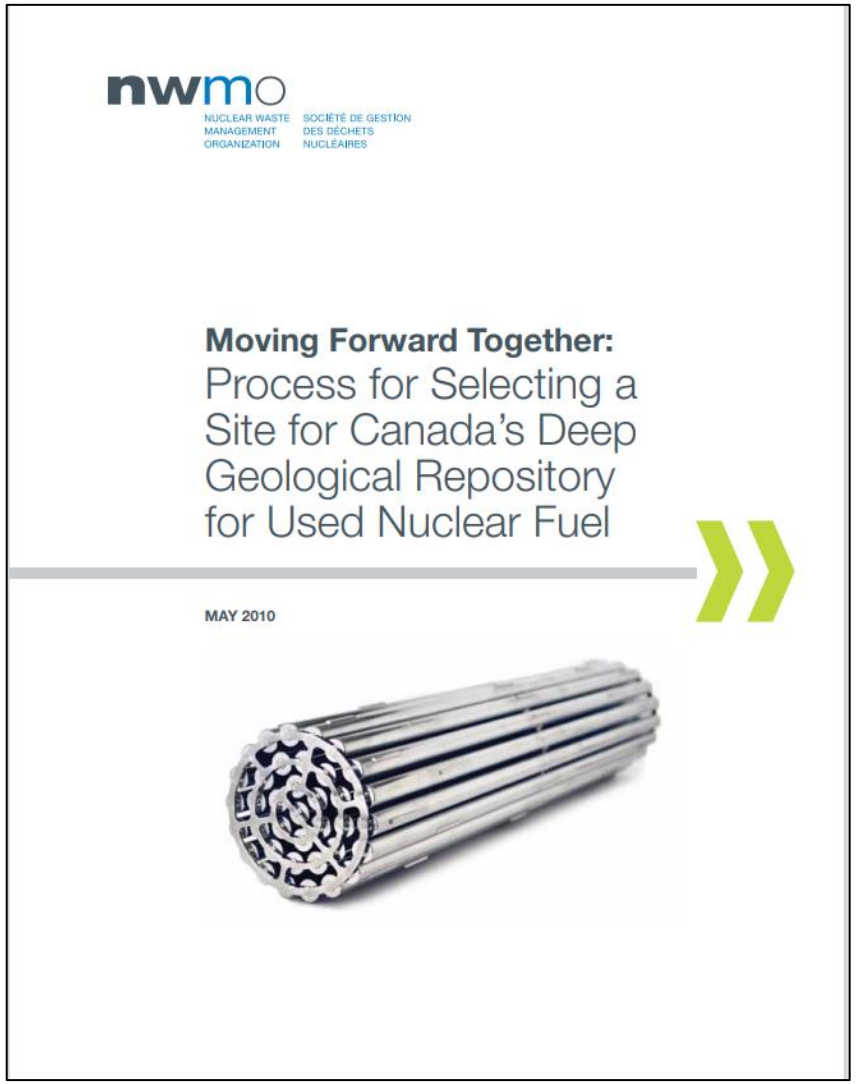



ALBERTA
SASKATCHEWAN
MANITOBA
ONTARIO
QUEBEC
TREATY #3 TERRITORY
Saukiing Anishnaabekiing
SAUGEEN OJIBWAY TERRITORY
Communities that expressed interest in the site selection process
Assessments underway in the area
5. Ignace
21. South Bruce
Communities not identified for further study
1. English River First Nation
2. Pinehouse
3. Creighton
4. Ear Falls
6. Red Rock
7. Nipigon
8. Schreiber
9. Manitouwadge
10. Hornepayne
11. White River
12. Wawa
13. Blind River
14. Elliot Lake
15. The North Shore
16. Spanish
17. Saugeen Shores
18. Arran-Elderslie
19. Huron-Kinloss
20. Brockton
22. Central Huron

Site Evaluation – A Geoscience Perspective

Site Selection Process (2010)
Guiding Principles: Focus on Safety

- Safety, security and protection of people and the environment are central to the siting process.
- Any site selected must address scientific and technical site evaluation factors that will acknowledge precaution and ensure protection of present and future generations and the environment for a very long period of time.



NWMO's Site Evaluation Process

Site evaluation process is driven by community's interest to participate.

Initial Screening
(Few months)

Desktop studies to evaluate the potential suitability of the community against a list of initial screening criteria

Preliminary Assessment
(Multiple years, 2 phases)

Technical and Social, economic and cultural assessments to determine whether a site in the community has the potential to meet the detailed requirements for the project:

- **PHASE 1:** Desktop for all communities
- **PHASE 2:** Field Work for a subset of communities

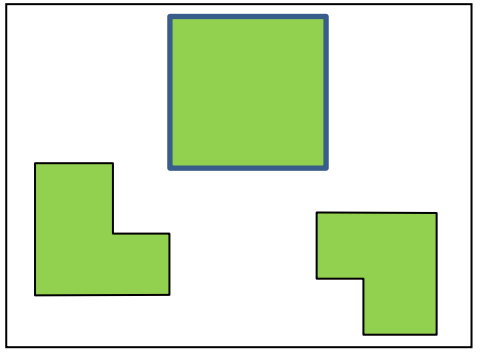
Detailed Site Characterization
(~potentially 3-5 years)

Detailed field investigations at one site to confirm suitability of the site based on detailed site evaluation criteria:

- Technical evaluation (detailed field investigations)
- Continue social, economic and cultural assessment

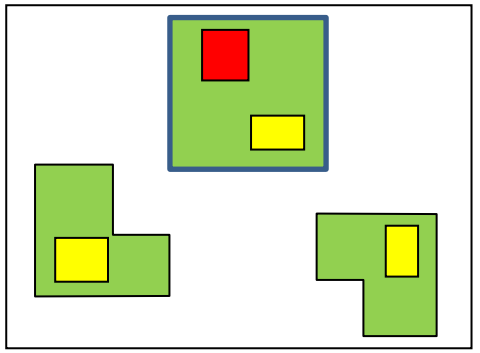
Preliminary Assessment Phases

PHASE 1
Desktop
For all communities



- Are there any general areas that may contain potentially suitable site?

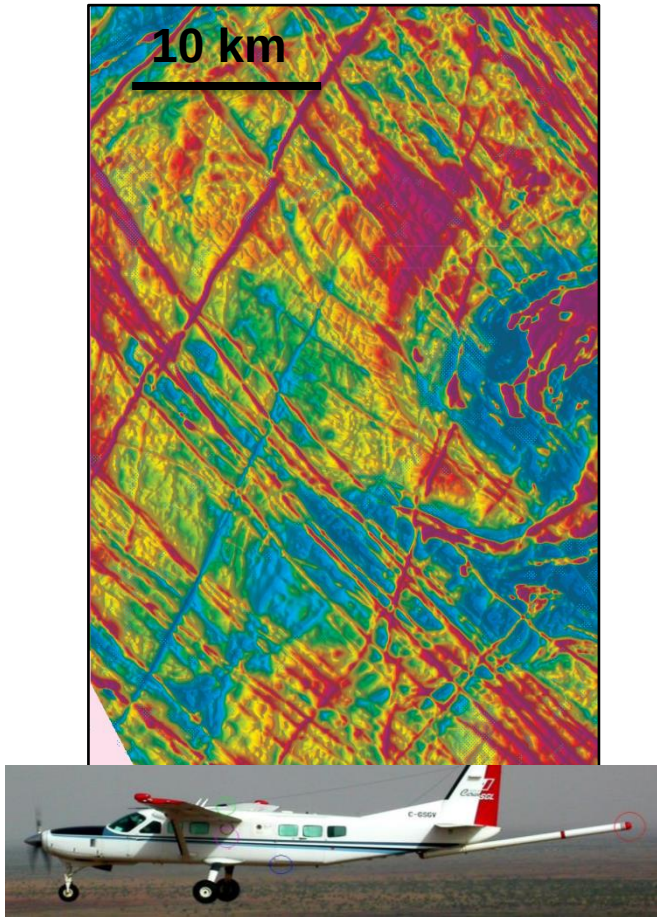
PHASE 2
Field Work
For a subset of communities



- Is there a potential to find repository-scale sites?
- Focused borehole drilling in selected areas

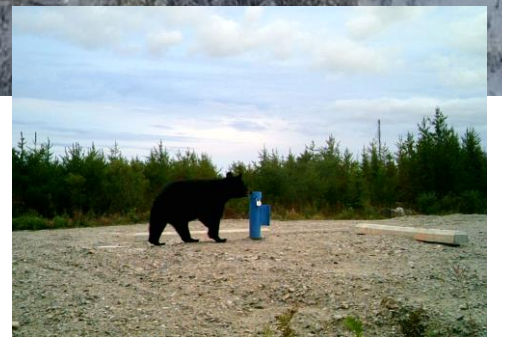
Preliminary Assessments: Field Work

- Airborne Geophysics Acquisition



- Geological Field Mapping

- Borehole Drilling &Testing

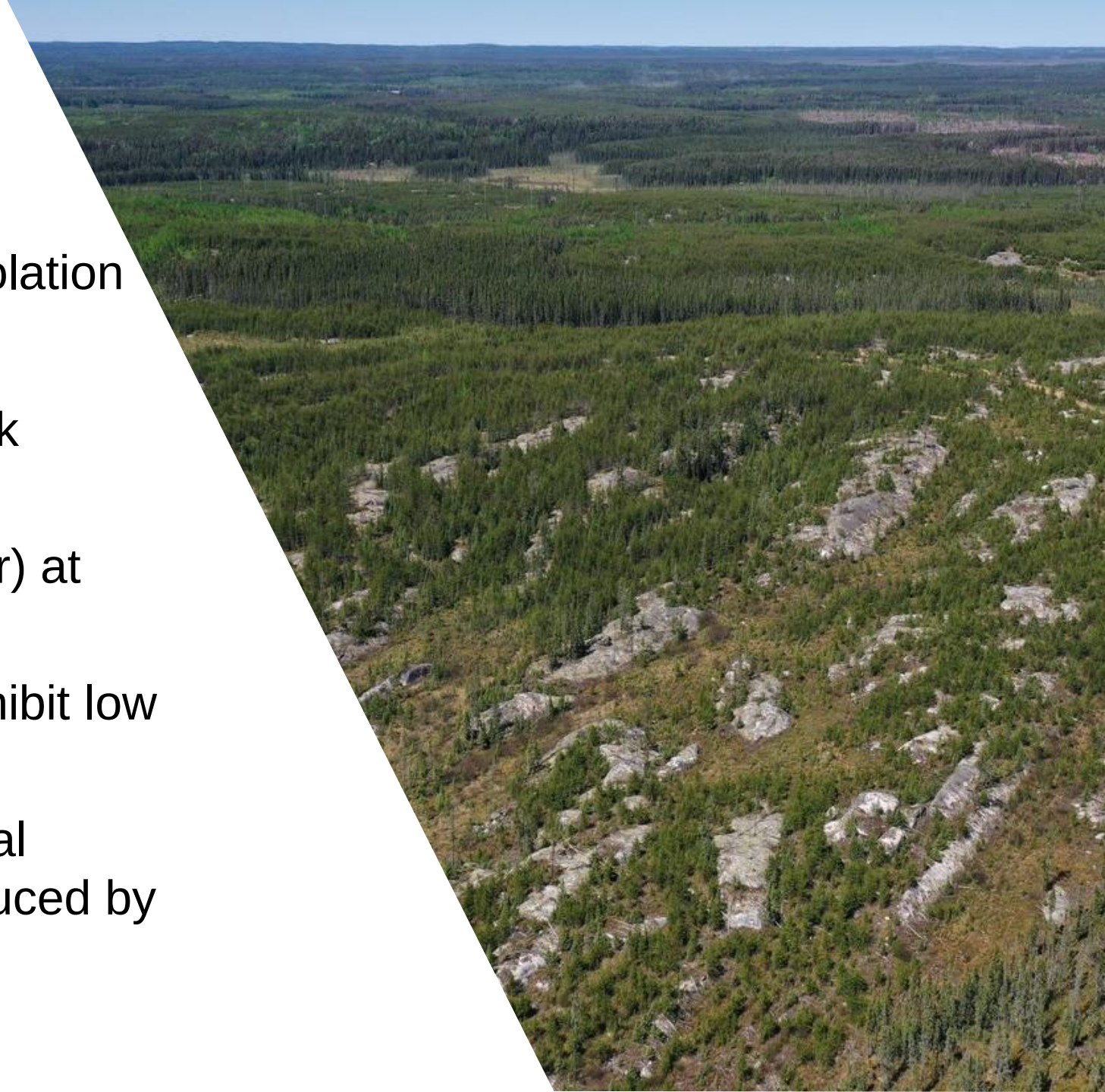


In Collaboration with Communities

Geoscientific Site Evaluation Factors

Safe, long-term, containment and isolation

- Depth of the proposed host rock
- Volume of available competent rock
- Rock mineralogy and geochemical conditions (groundwater, porewater) at repository depth
- Hydrogeological regime should exhibit low groundwater velocities
- Host rock ability to withstand natural stresses, and thermal stresses induced by the repository

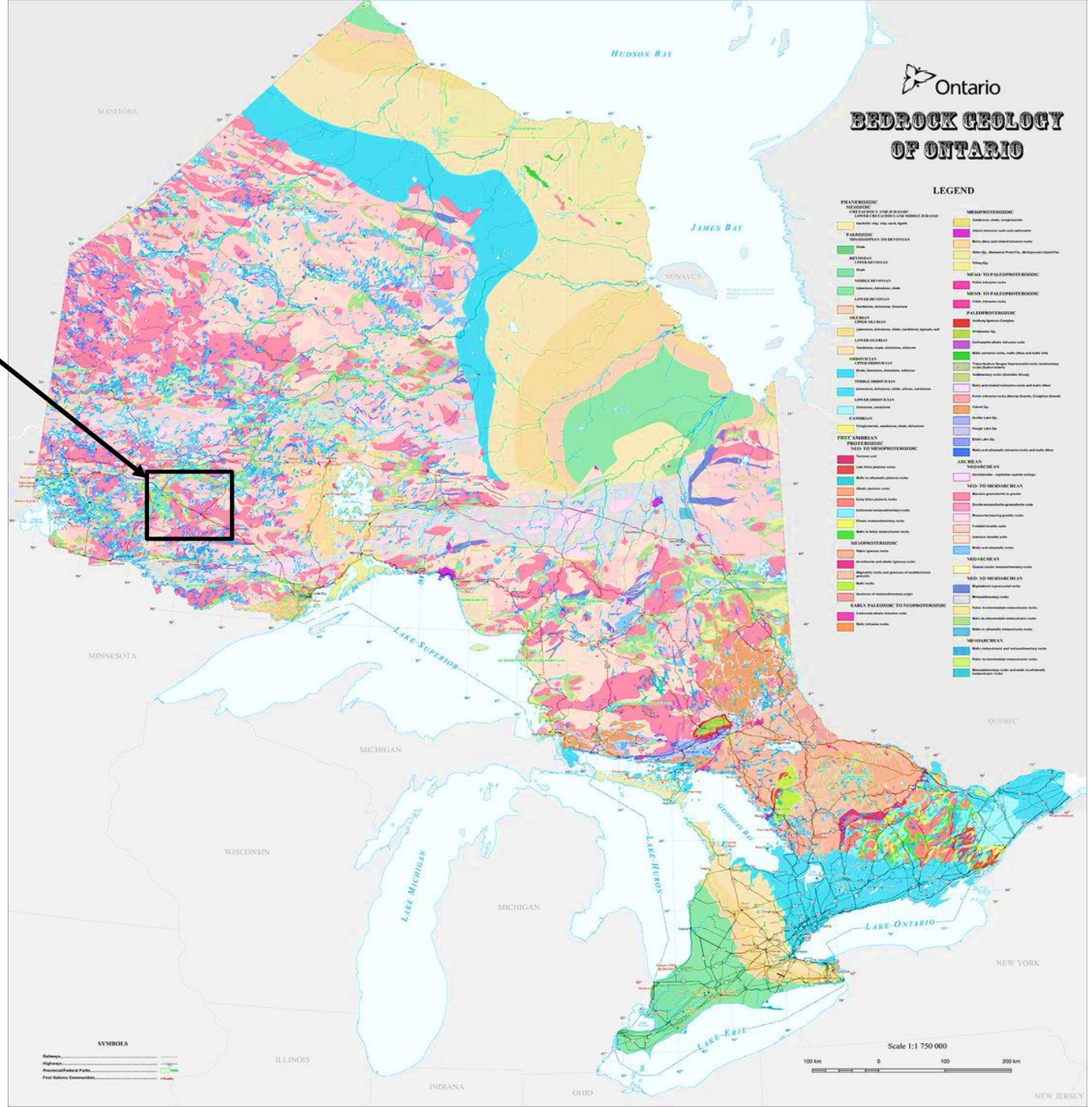


Crystalline Site Geoscientific Characterization Program

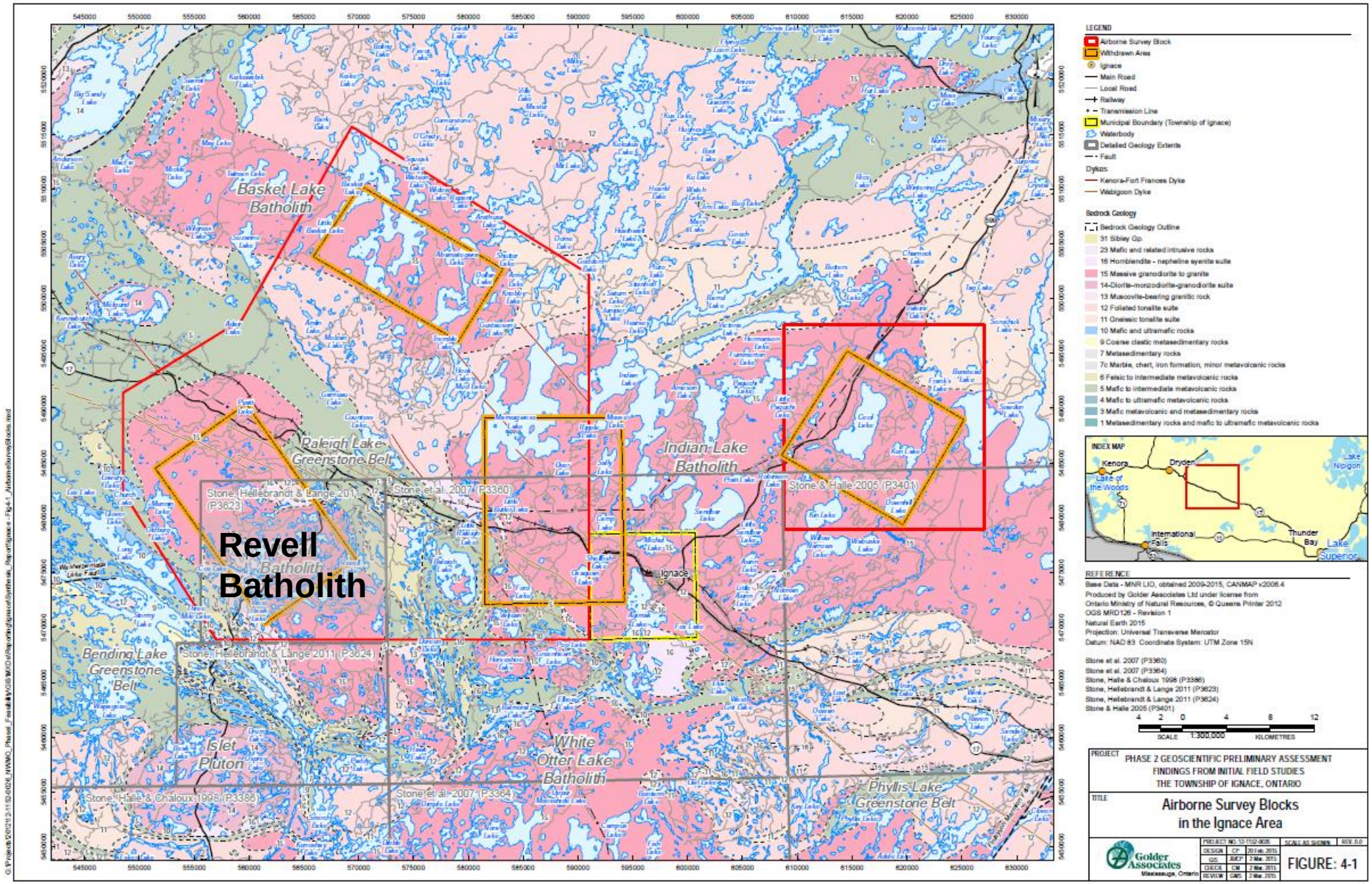
Wabigoon Lake Ojibway Nation (WLON) - Ignace Area

Northwestern Ontario

>2.5 billion year old "crystalline rock"

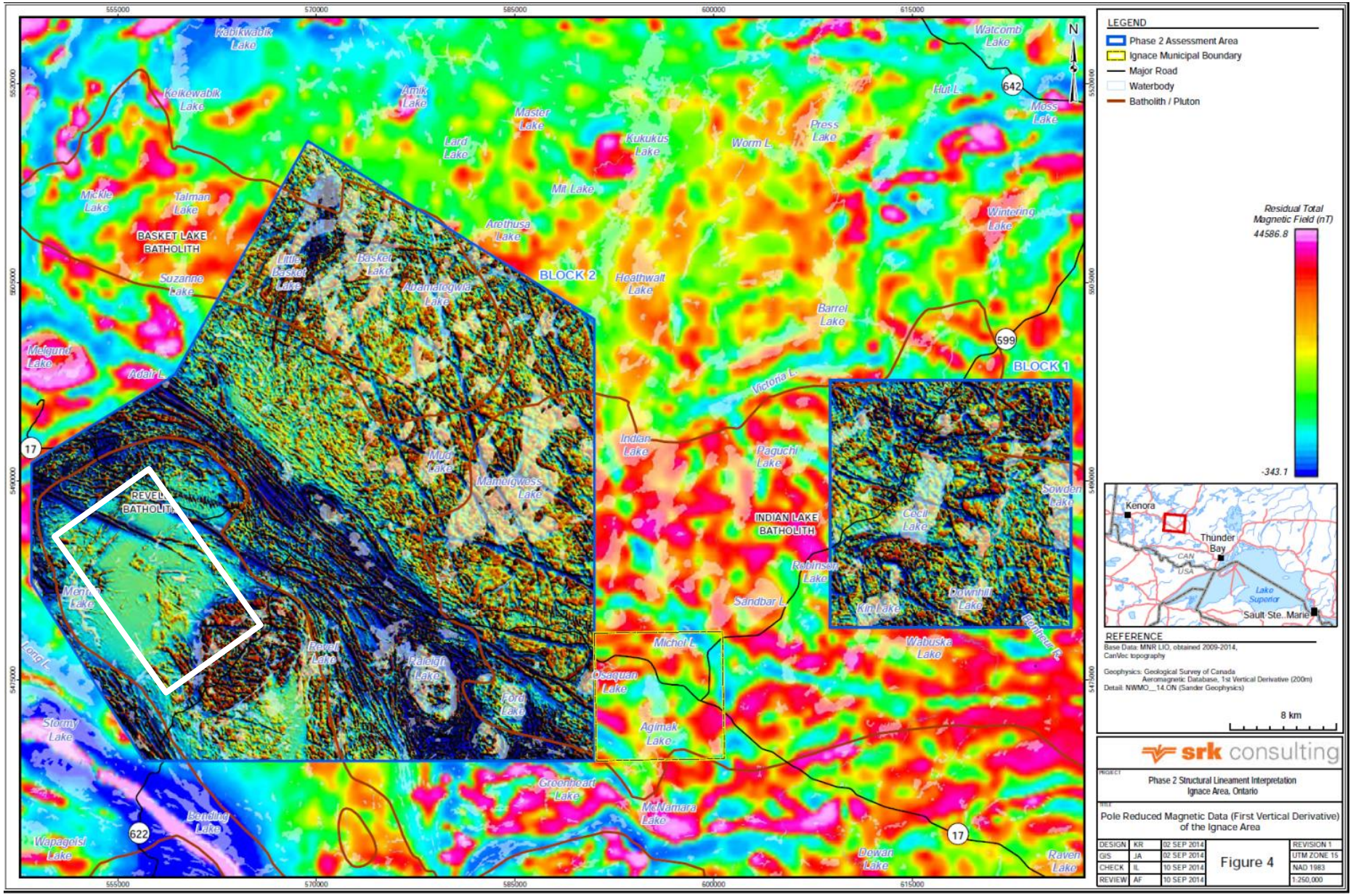


Narrowing down in the WLON-Ignace area



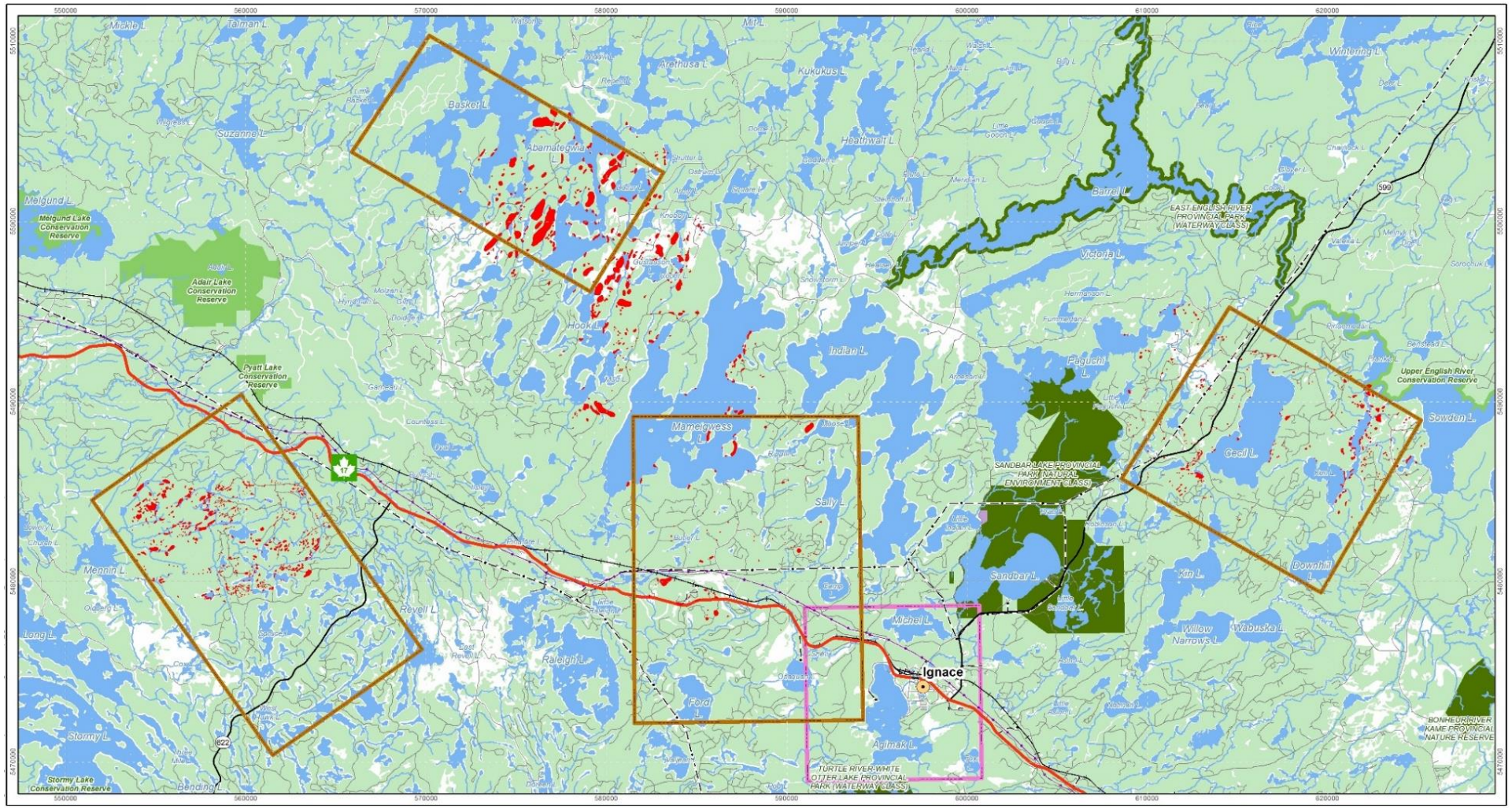
(from Golder, 2015)

Airborne geophysical surveys

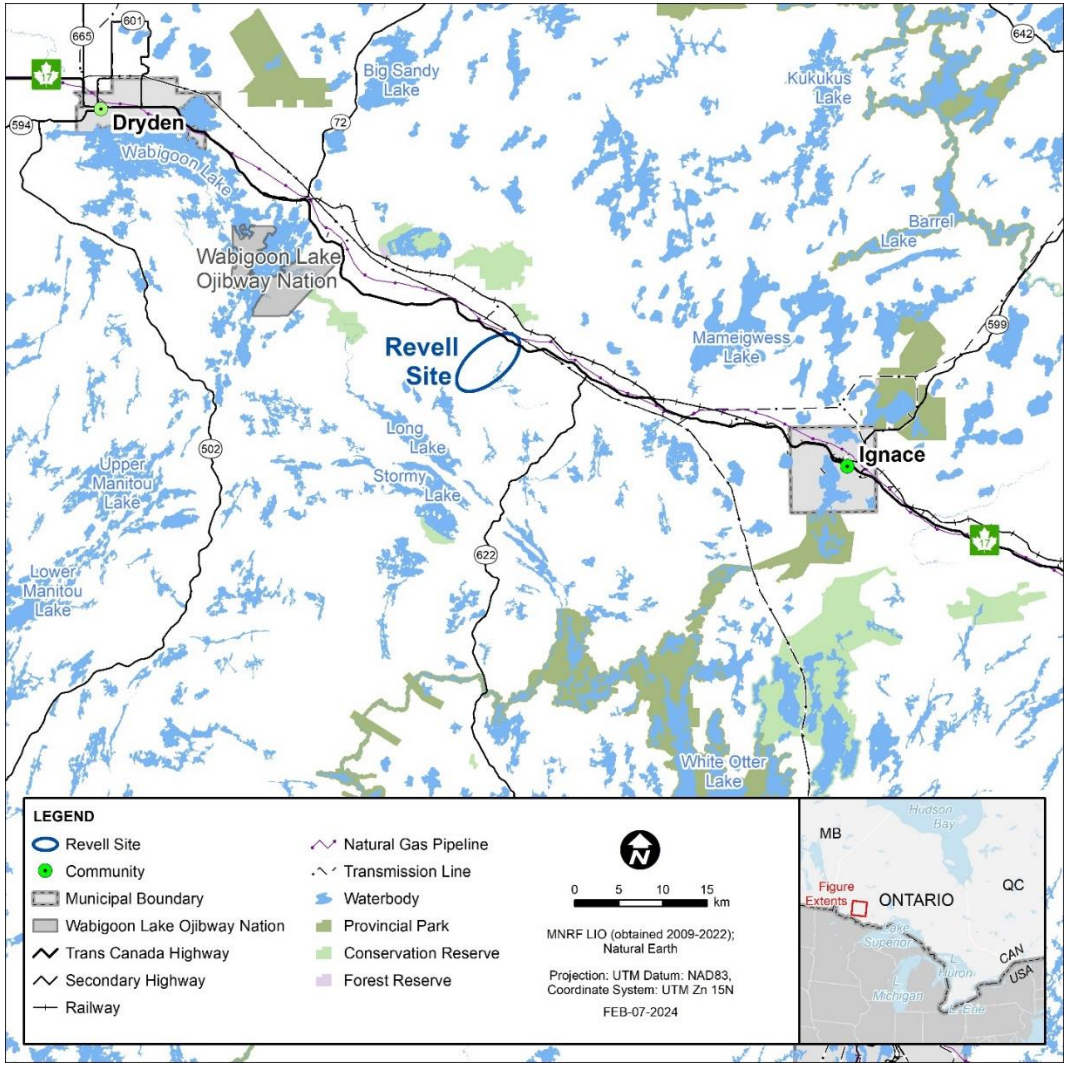


(from SRK, 2015)

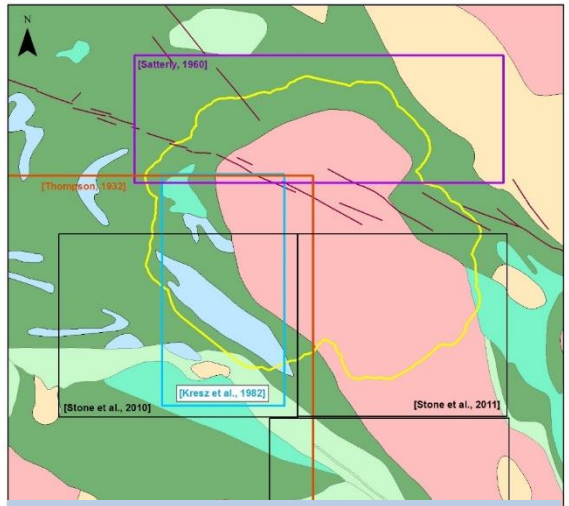
Predicted Outcrop Locations Using High-resolution Imagery- Ignace



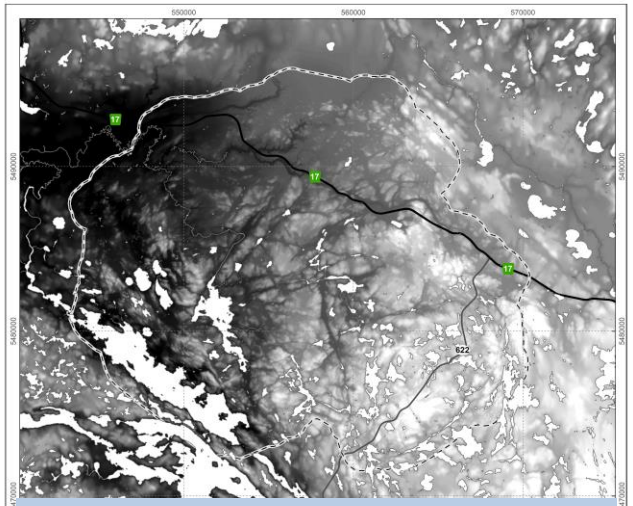
Potentially Geologically Suitable Area – Northern portion of the Revell batholith, the ‘Revell Site’



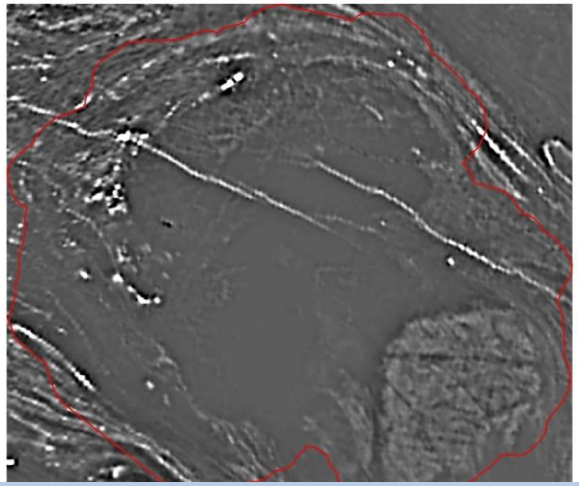
Updating the regional bedrock geology map



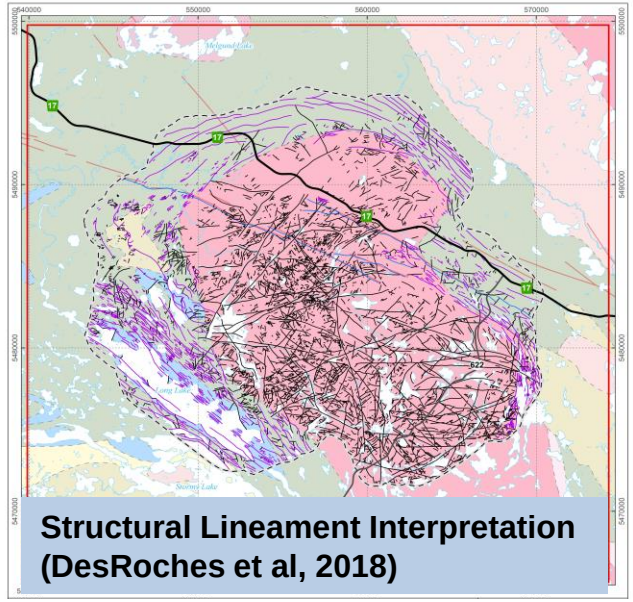
1:250 000 scale bedrock map (Ontario Geological Survey, 2011)



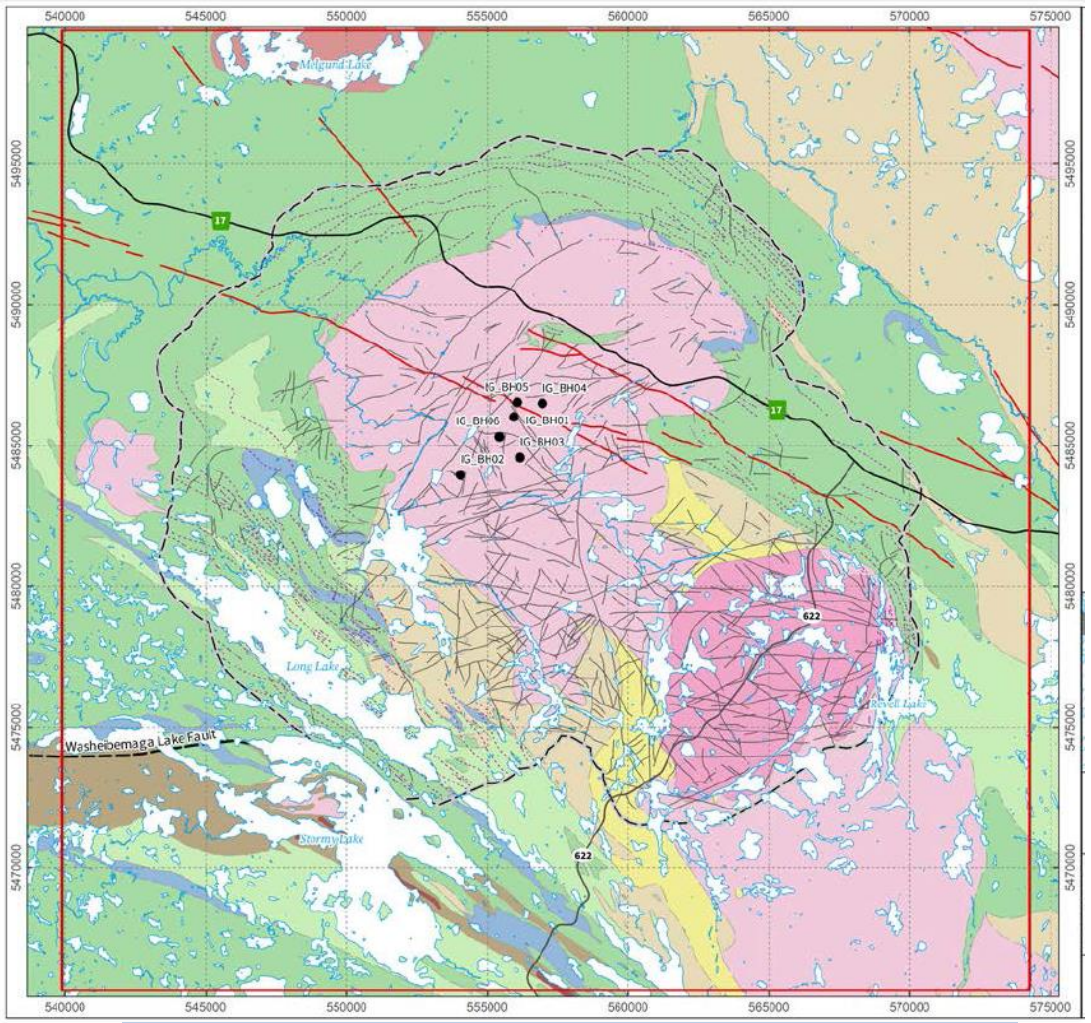
Digital Elevation Model derived from aerial LiDAR survey (ATLIS, 2018)



High-Resolution Airborne Magnetic Survey Data (SGL, 2015)

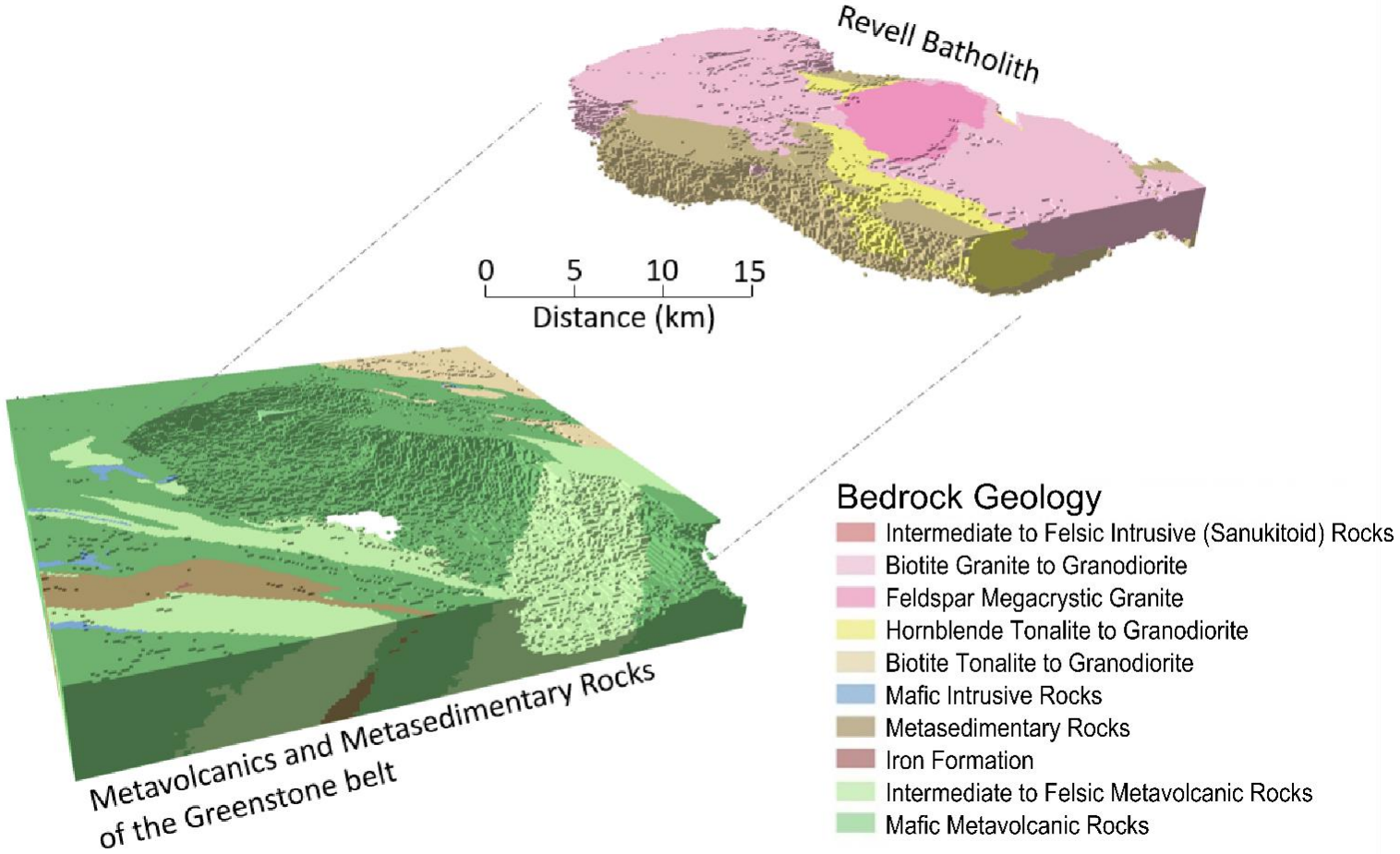


Structural Lineament Interpretation (DesRoches et al, 2018)



Two-dimensional (2D) bedrock geology map of the Revell batholith and surrounding area (Parmenter et al., 2020)

Development of a Regional 3D Geophysical Model using the 2D bedrock map



SGL

SANDER GEOPHYSICS

A key outcome of this work was the understanding that the Revell batholith extends for approximately 2.5-3.0 km beneath our area of interest (SGL, 2020)

nwmo

Borehole Drilling, Coring and Testing


IG_BH05
IG_BH04
IG_BH01
IG_BH06
IG_BH03
IG_BH02
1350 m
Image © 2022 Maxar Technologies
Google Earth

Site Access (~5km of access roads)

Revell Site - Deep Borehole Drilling, Coring & Testing

- Six boreholes drilled to 1,000 m depth each
- One borehole vertical, five inclined ~70 deg
- HQ3 size borehole (96 mm drilling, 61 mm core)

Objectives:

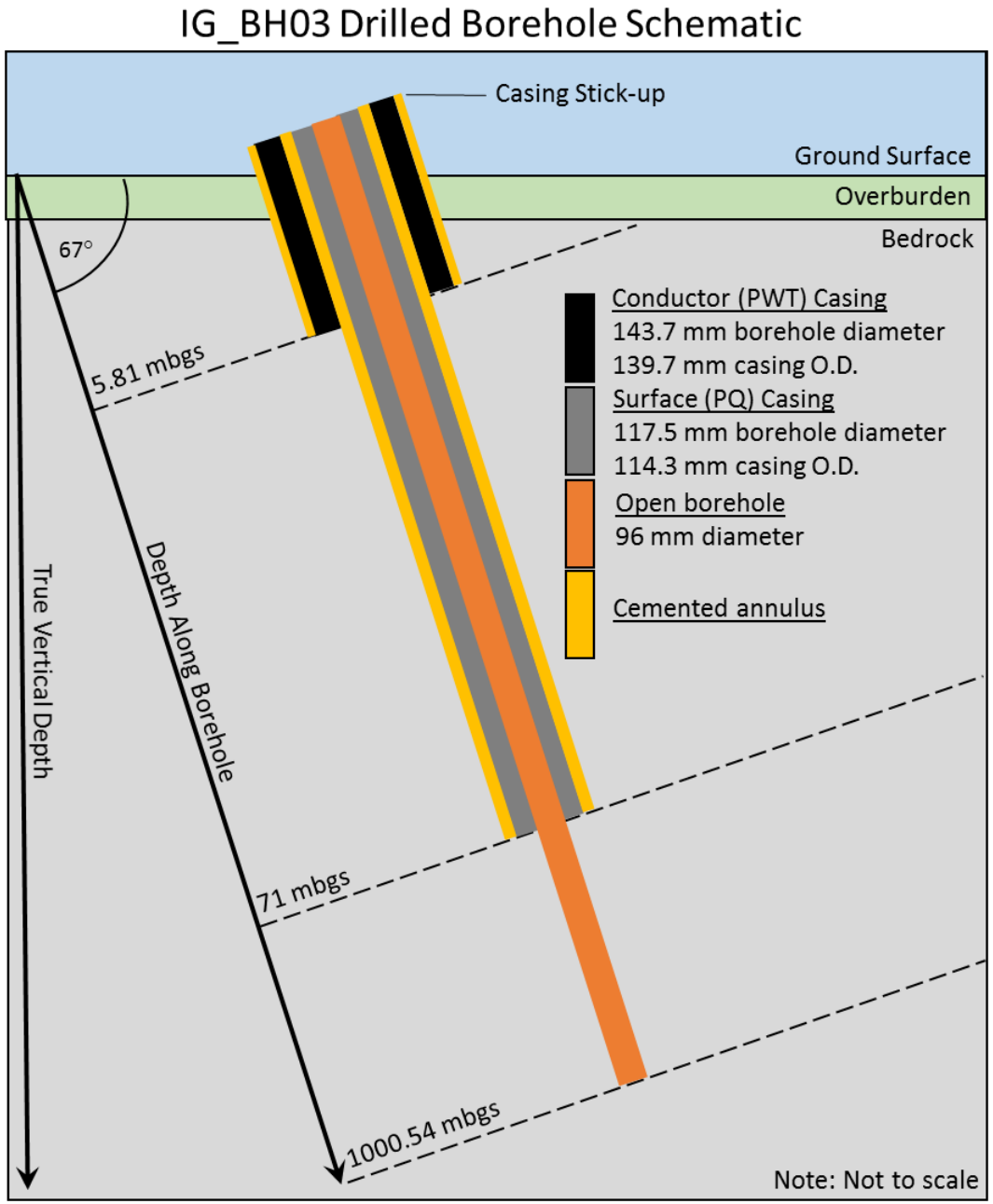
- Main objective is to collect geoscientific information from the subsurface to contribute to the assessment of site suitability.
- Specific objectives:
  - Collect direct information on bedrock/fractures
  - Collect groundwater samples;
  - Collect rock core for logging, analysis and laboratory testing;
  - Allow for downhole testing; and,
  - Allow for long-term monitoring.

Core Sampling

BH03 Borehole Construction

Casing Type	Outer Diameter (mm)	Inner Diameter (mm)	Depth (m)
Conductor (PWT) Casing	139.7	127.0	5.81
Surface (PQ) Casing	117.5	103.2	71
HQ3 Drill Bit	96.0	61.1	N/A

Depth from (mbgs)	Depth to (mbgs)	Diameter Type	Borehole Diameter (mm)
0	5.81	PW Casing Shoe	143.76
5.81	71	PQ Casing Shoe	117.5
71	1000.54	HQ Drill Bit	96



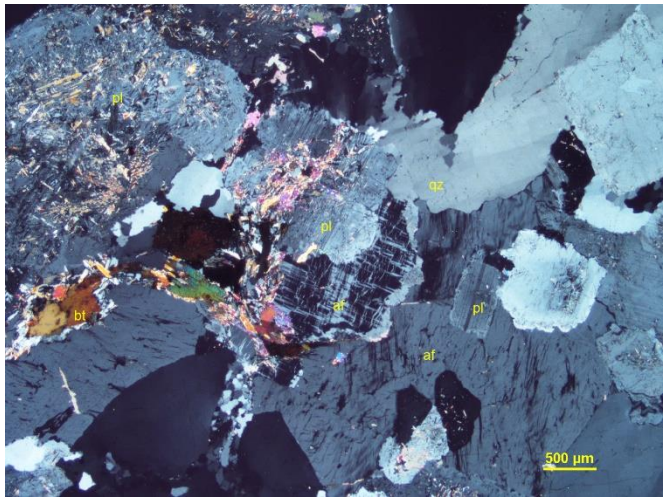
Borehole diameter – 96 mm. Core diameter (HQ3) – 61.1 mm.
Total of 10 drill bits used for BH01 with an average duration of around 100 m per bit.

Laboratory Testing of Core Samples

Geomechanical and Thermal Testing

Porewater Extraction & Analysis

Mineralogy & Whole rock Geochemistry

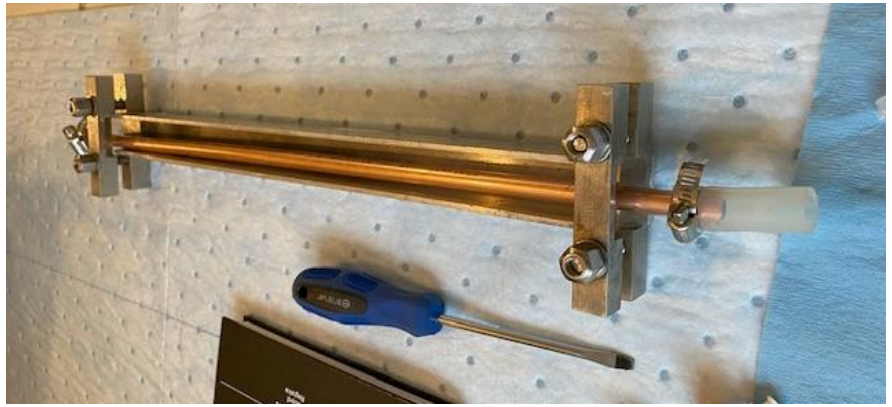


Sorption Testing

Opportunistic Groundwater Samples

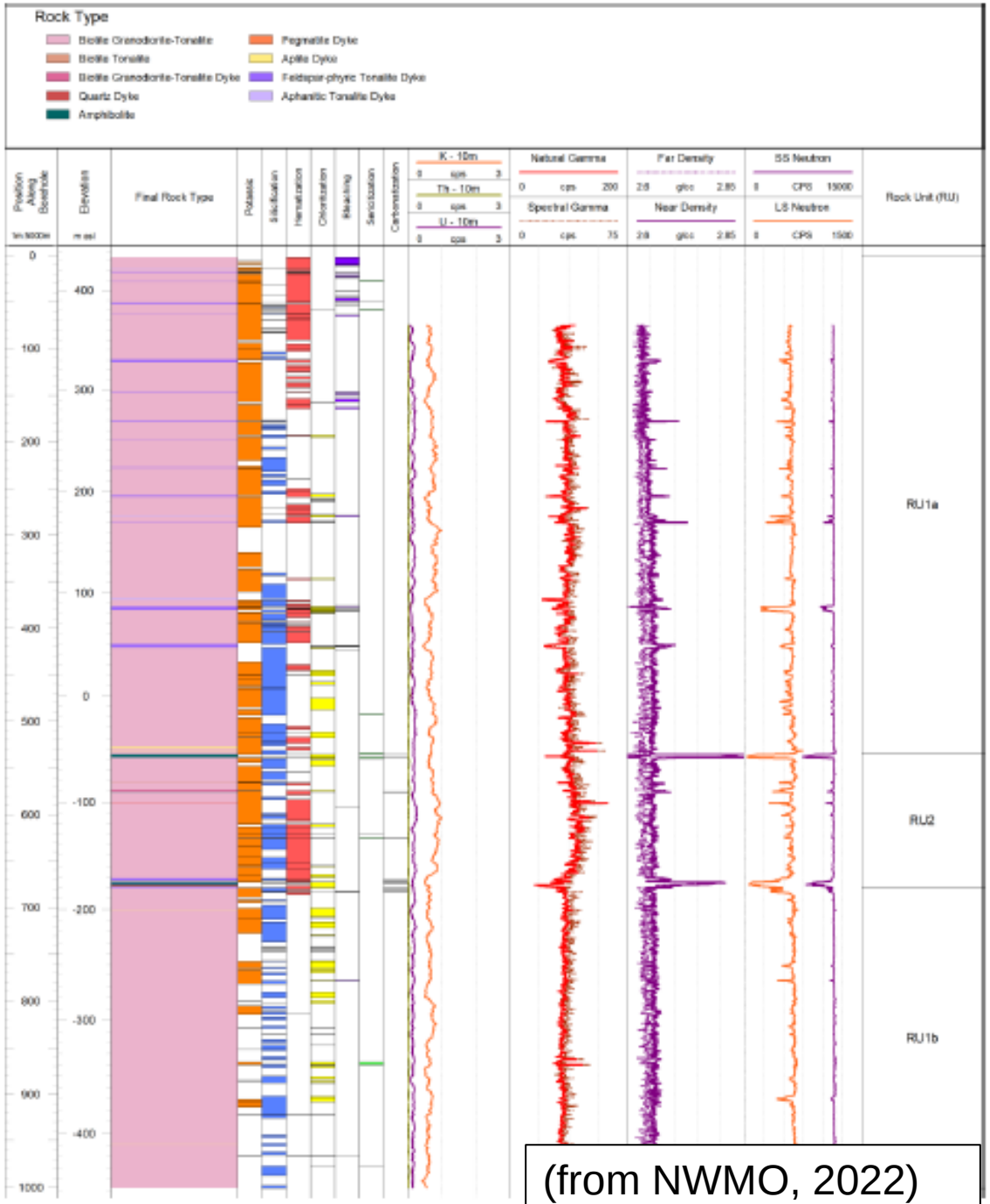
Purpose: To understand and characterize fluids at depth and to demonstrate that fluids at repository depth have not been in contact with shallow groundwater for very long time periods.

- “First-strike” samples minimizes mixing.
- Taken during drilling when a trigger indicates a sample is possible.
- Purged for up to 72 hours or more.
- Fluorescein tracer.
- Flow-through cells
- Downhole sampler (Mount Sopris or Westbay)
- Sealed copper tubes (Noble gases).



Geophysical Logging

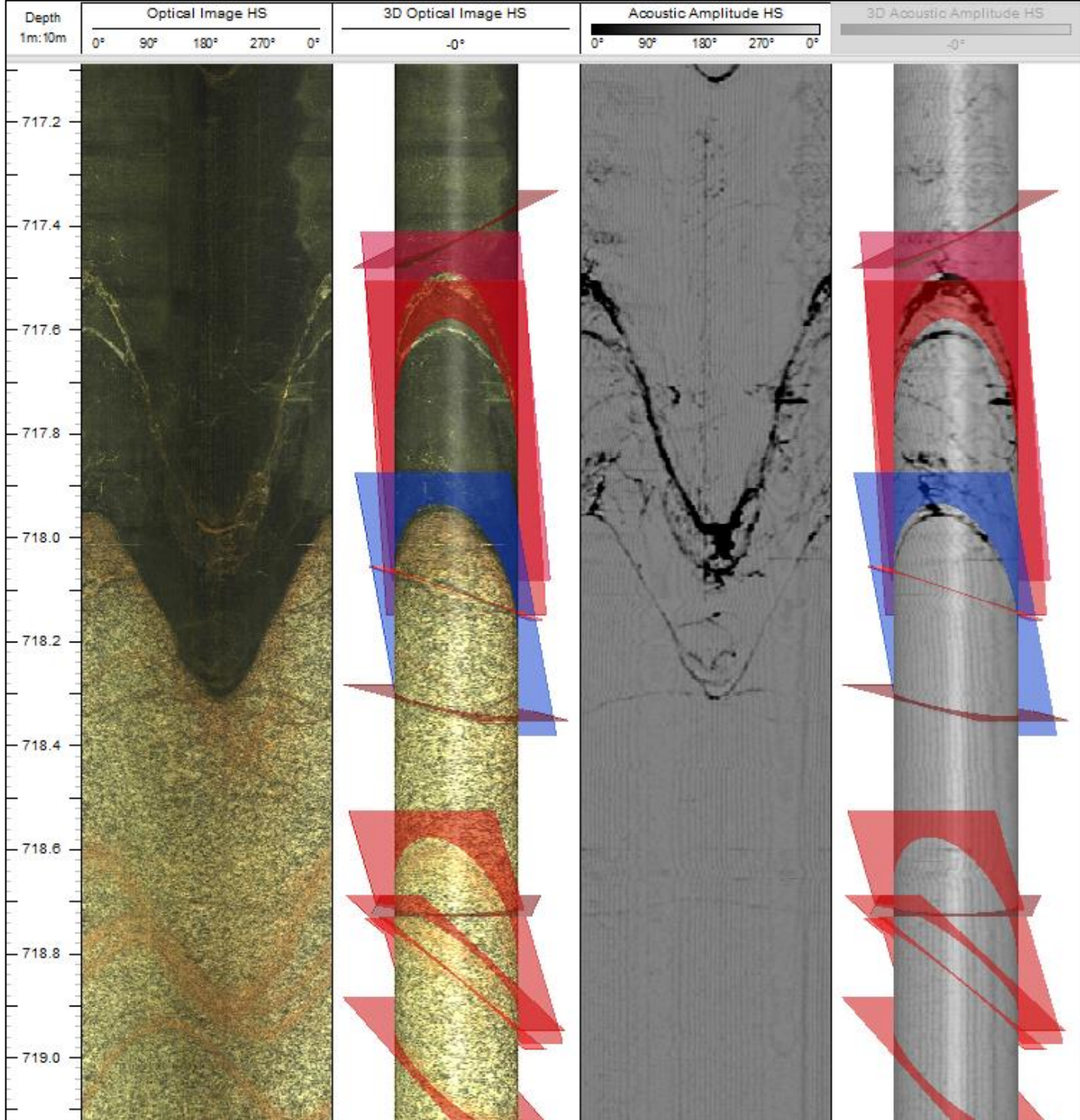
- Sensors are lowered into the borehole to record rock/fluid physical parameters with depth
- Recorded physical data is processed and interpreted to obtain information on the rock (e.g., type, fractures)
- Key inputs to geological data integration



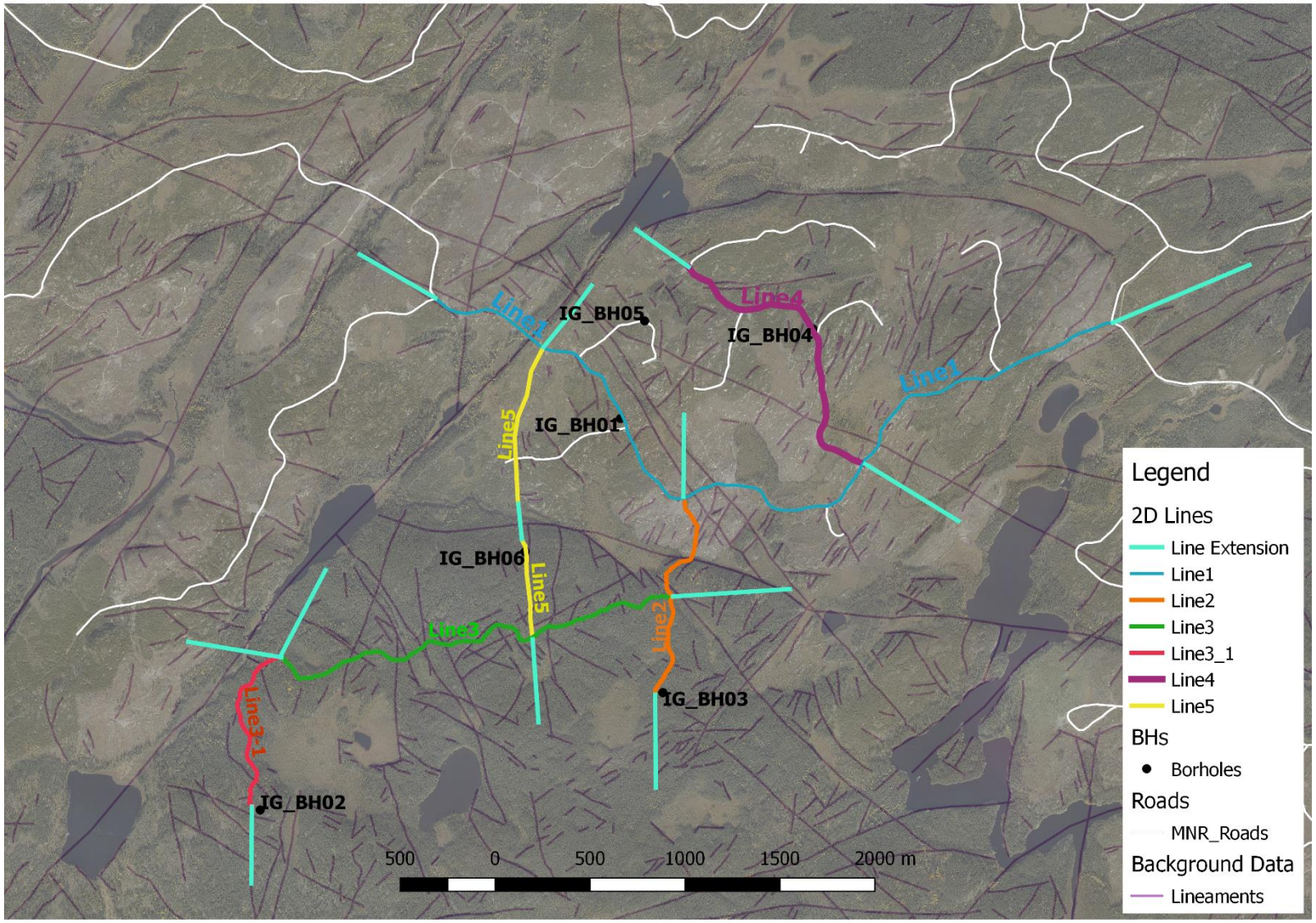
(from NWMO, 2022)

Televiewer fracture mapping

- Structural characteristics, rock type changes, measured from borehole televiewer images
  - depth,
  - true orientation,
  - geologic aperture,
  - alteration (qualitative)

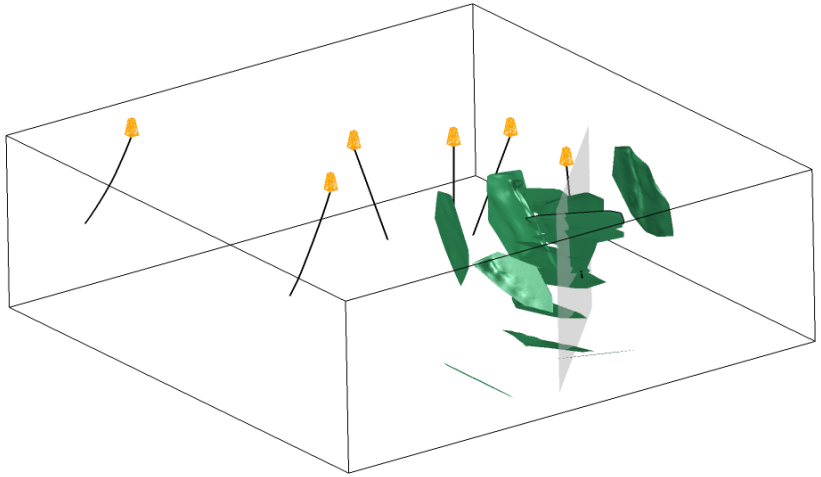


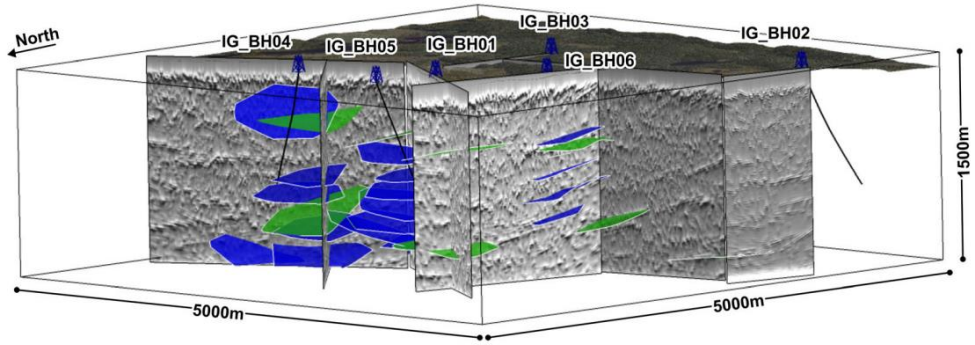
2D Seismic Investigation

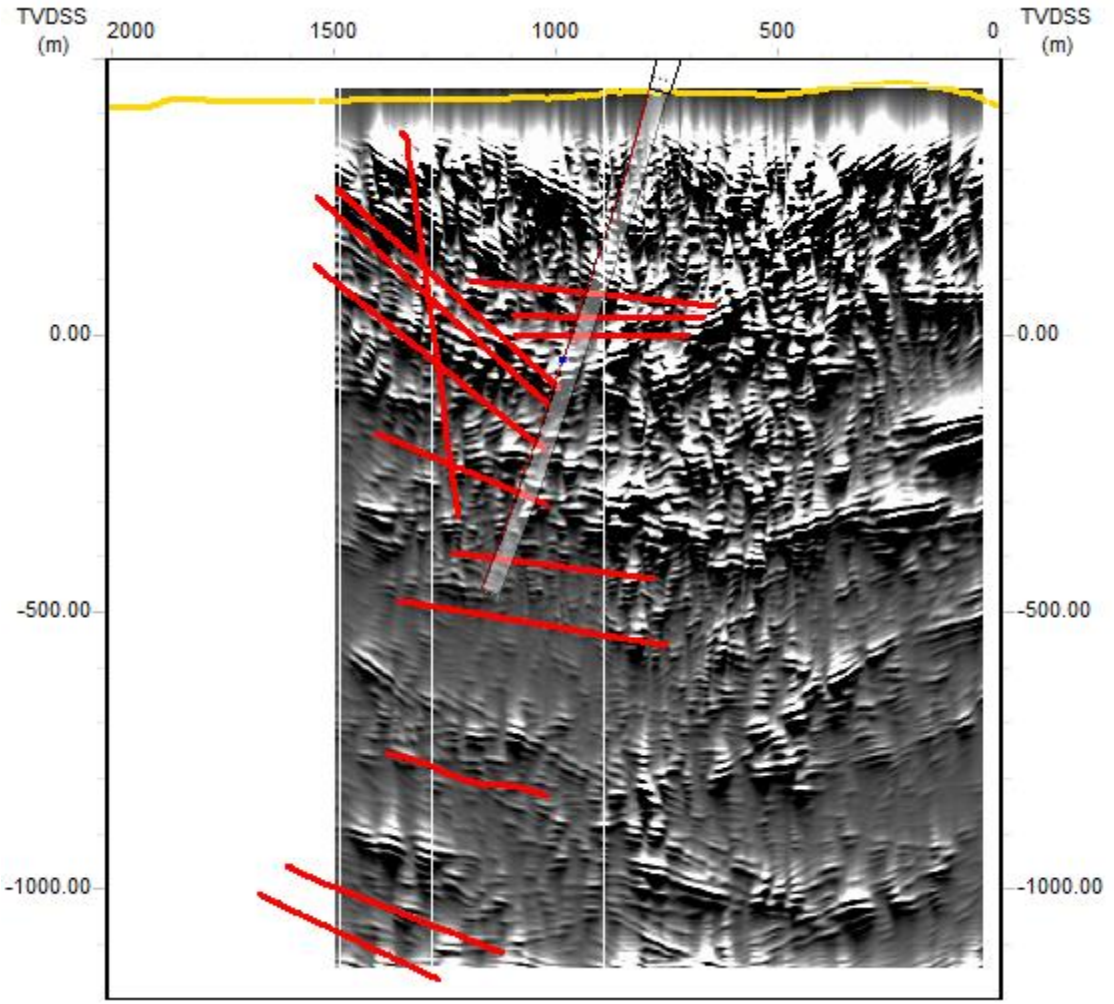


- Approximately 17 km of seismic lines
- Acquisition along existing logging roads, maximizing coverage
- Imaging down to approx. 1,500 m in the subsurface

Vertical Seismic Profiling (VSP) Reflectors with High Certainty







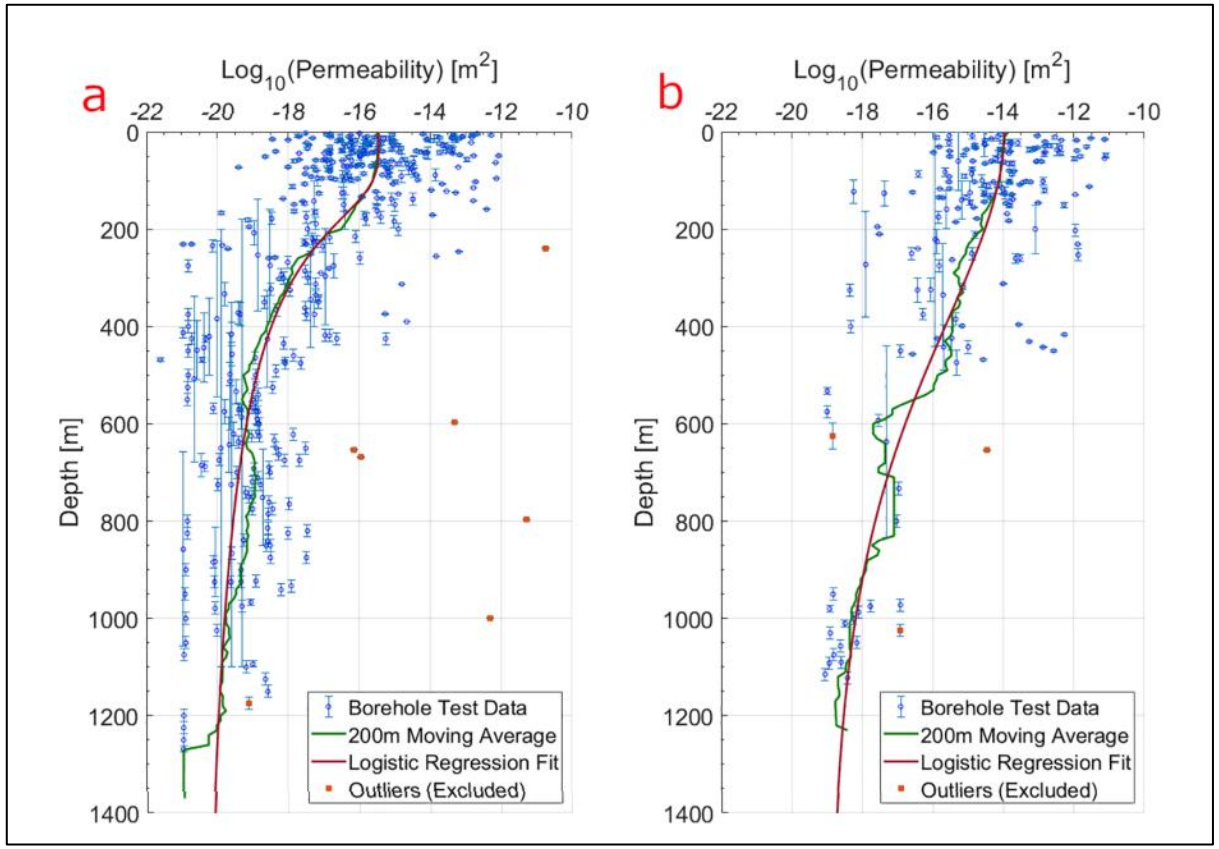
From Villamizar et al. (2023)

Hydraulic Testing

Objective: to interpret the hydraulic conductivity ("*how fast/slow the water moves through the rock*") of specific intervals in the borehole

Scope:

- Water is pumped from isolated intervals, and pressure response measured.
- Changes in pressure can be interpreted to derive hydraulic conductivity values.
- Tested 20-30 intervals per borehole



Permeability measurements for a) Equivalent Porous Media Rock Mass and b) fracture zones in the Canadian Shield from Atomic Energy of Canada (AECL) research areas (Snowdon et al., 2021)

Borehole Long-Term Monitoring

Monitoring of IG_BH01, IG_BH03, IG_BH05 and IG_BH06

- Long-term pressure monitoring (quarterly)
- Extended purging and groundwater sampling and analysis.

Groundwater Monitoring Well Network

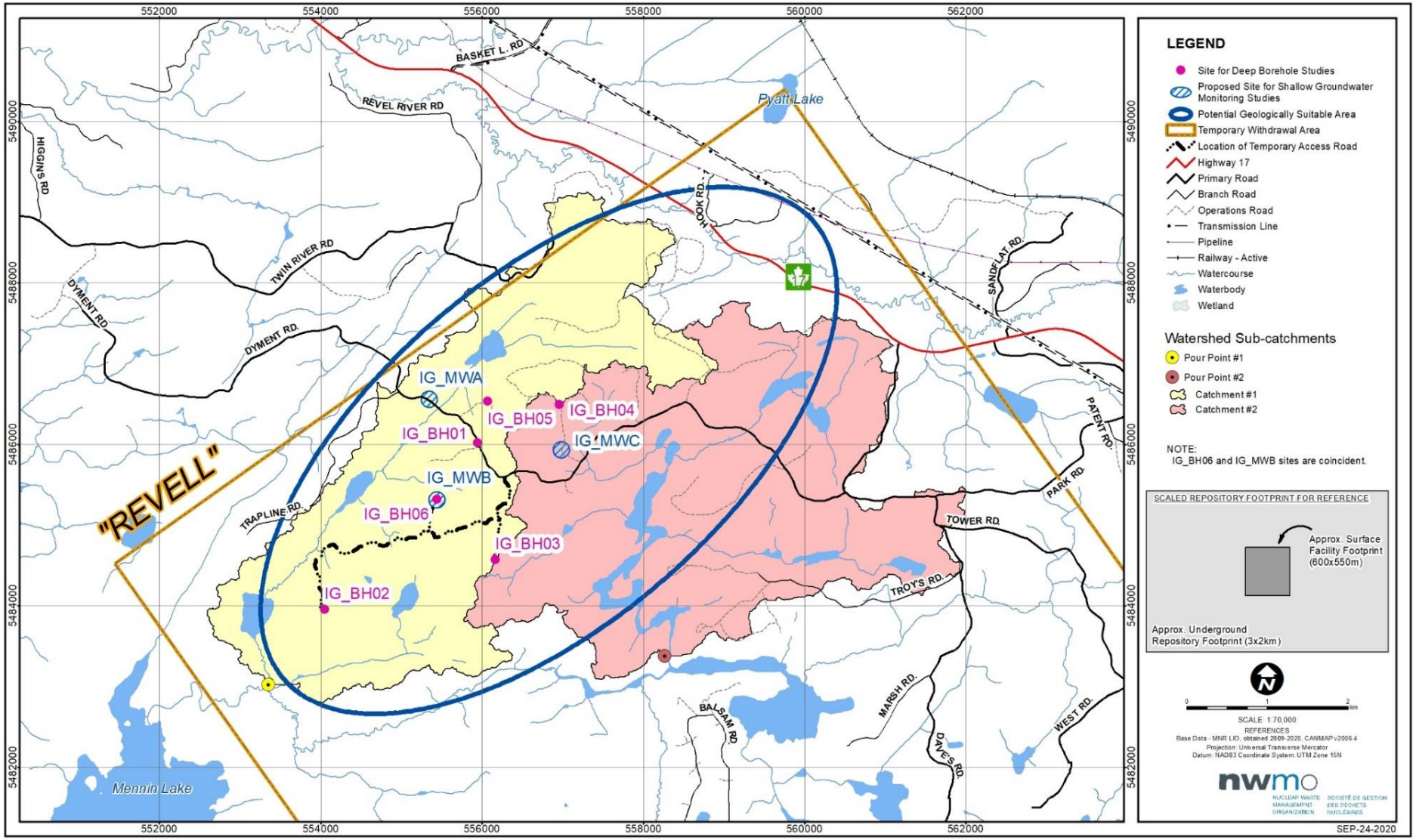
Main Objectives:

- Assess baseline conditions of local shallow groundwater: water table elevation and seasonal fluctuations, hydraulic gradients, groundwater chemistry, shallow bedrock hydraulic conductivity.
- Address hydraulic influence of near surface bedrock fractures on shallow groundwater system.
- Provide support for surface boundary condition assumptions in groundwater flow modelling.

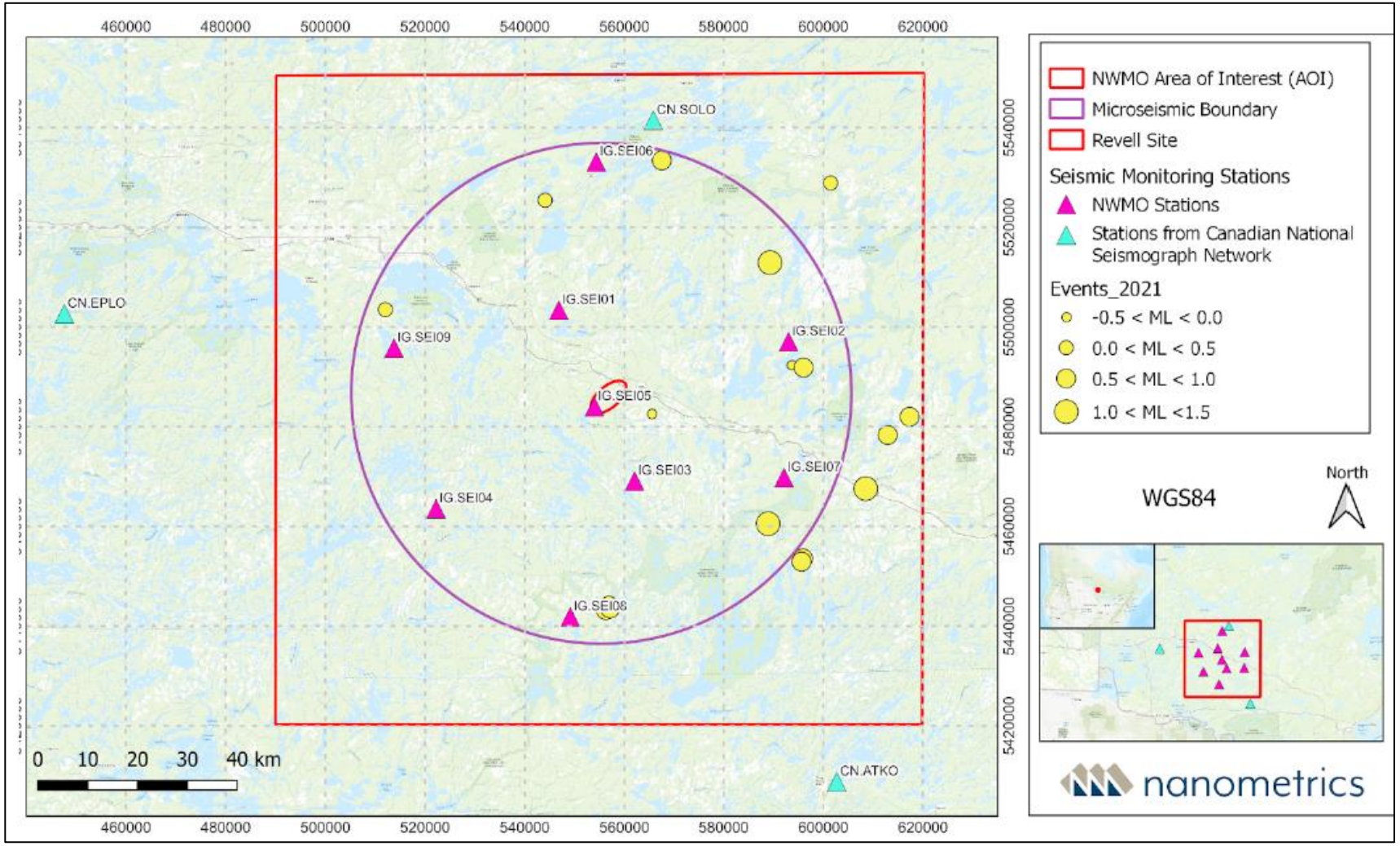
Scope:

- Drilling of a total of nine (9) boreholes to a maximum depth of 100 m, at three sites near existing roads.
- At each site - *three wells located 50m apart in a triangulated configuration*
- Acquisition of geophysical logging
- Installation of monitoring system

Groundwater Monitoring Well Network



Regional Microseismic Network



Seismic events observed within the AOI from November 2020 to December 2021(from Nanometrics, 2022)

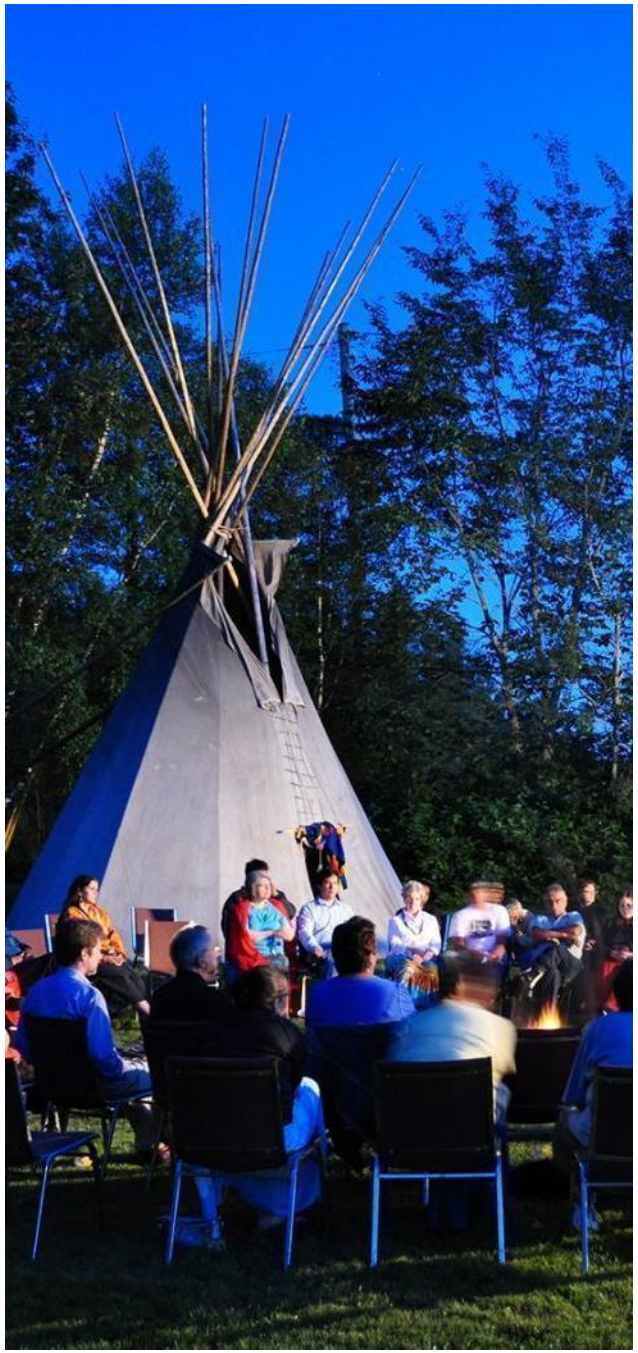
Station at IG_BH02

- Network identifies events of magnitude as low as 1.0 Mw within ~50km of the site.

3. Lessons Learned

Incorporate Indigenous Traditional Knowledge

- Knowledge about the land and ecology stemming from long contact with the land
- Knowledge about developing and maintaining effective and meaningful relationships between generations and within and between communities
- Special understanding of the broad range of factors that should be considered, and the processes that should be used, in assessing the appropriateness of any site

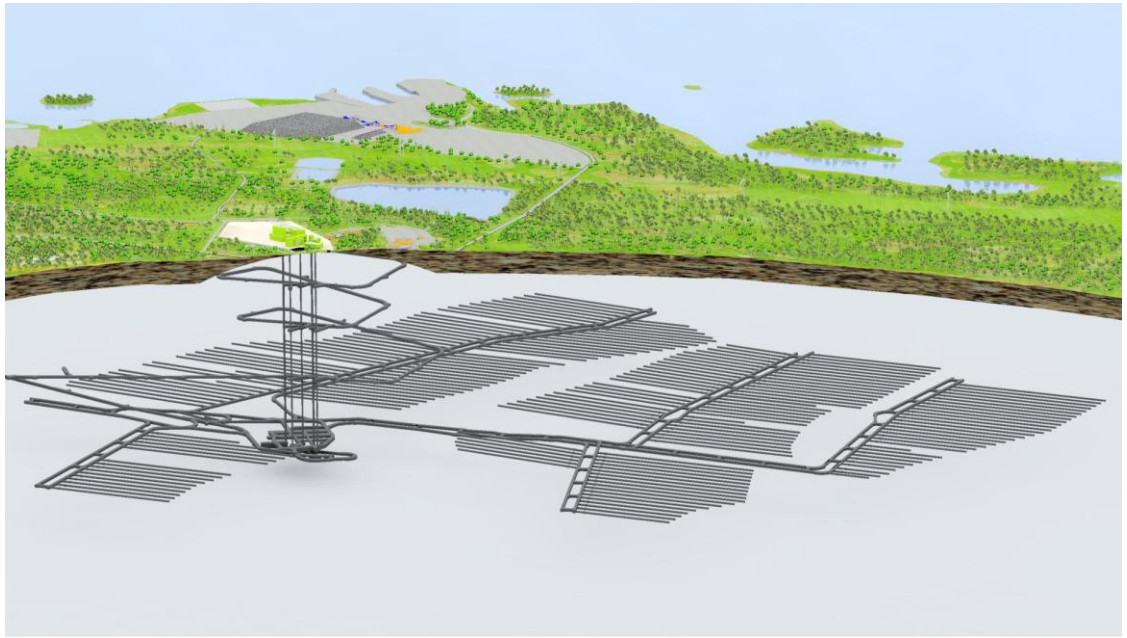



FIRE EXTINGUISHER
ISHKODE AATE'IGAN
GOLDER OFFICE
GOLDER OZHIBII'IGEWIGAMIG
CONSTRUCTION SITE
GAAZHIANOKIIWAT
MUST BE WORN ON THIS SITE
OHIGIZHI GATE GIN
SITE OFFICE
MUSTER POINT
GEZHINAGATAWING
EYE WASH STATION
gizhkigoongazhigiziibinigategin
FIRST AID STATION
NADAWEGAMIG
BACK IN ONLY
CHIAZHEBIZOOIN ATA
WELCOME
BOZHOO
MANDATORY Personal Protective Equipment
OHIGIZHI GATE GIN
CHANGE
AANJI
THINK
GWAYAKWENDAN
OBSERVE
NAAGADAWAABAM
PLAN
ONAAKONAN
CAUTION
ONGWAAMIZIWAG
RESTRICTED AREA
GAAZHIAANOKII WAT
EQUIPMENT OPERATING
CHIBIISKAMAN AKEWE BICHAZHAIN
PERSONAL PROTECTIVE EQUIPMENT REQUIRED
OHIGIZHI GATE GIN
GASOLINE TANK
TAZHOBIGATE PIIZHKIN WASOGAMITE
FLAMMABLE
BAAZH GIDEMIGAN
NO SMOKING
GAGOCHI"IMAA EHIZAGUAIN
DESIGNATED SMOKING AREA
MII IMAACHIZAGASWONG

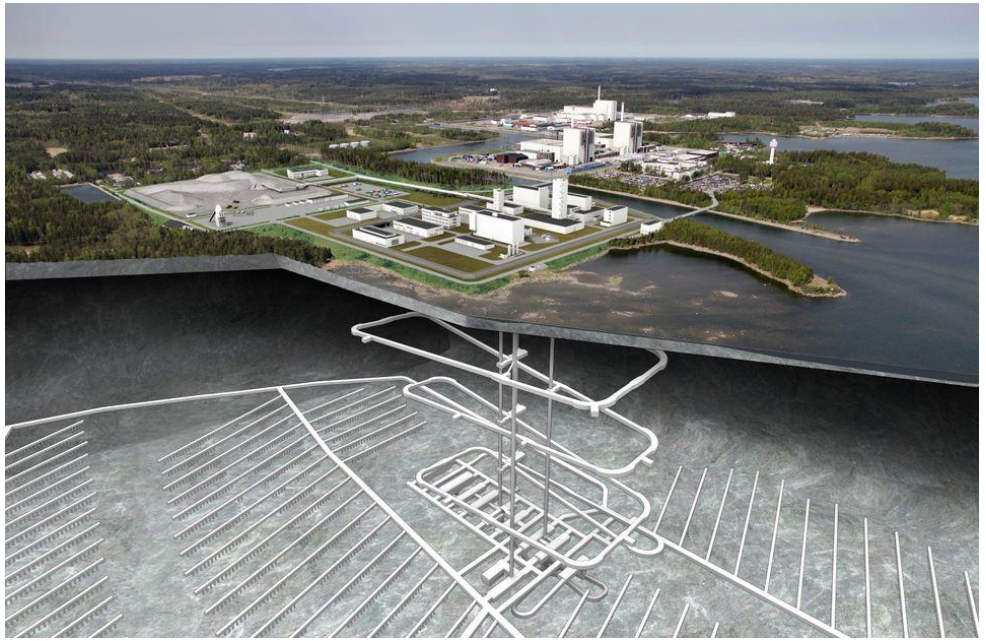
Demonstrate Commitment to Protecting People and the Environment

Learn from International Precedence and Experience

Northwestern Ontario crystalline rock setting is broadly similar to those selected in Finland and Sweden for a used fuel repository.



Proposed Finnish facility (Source: Posiva)



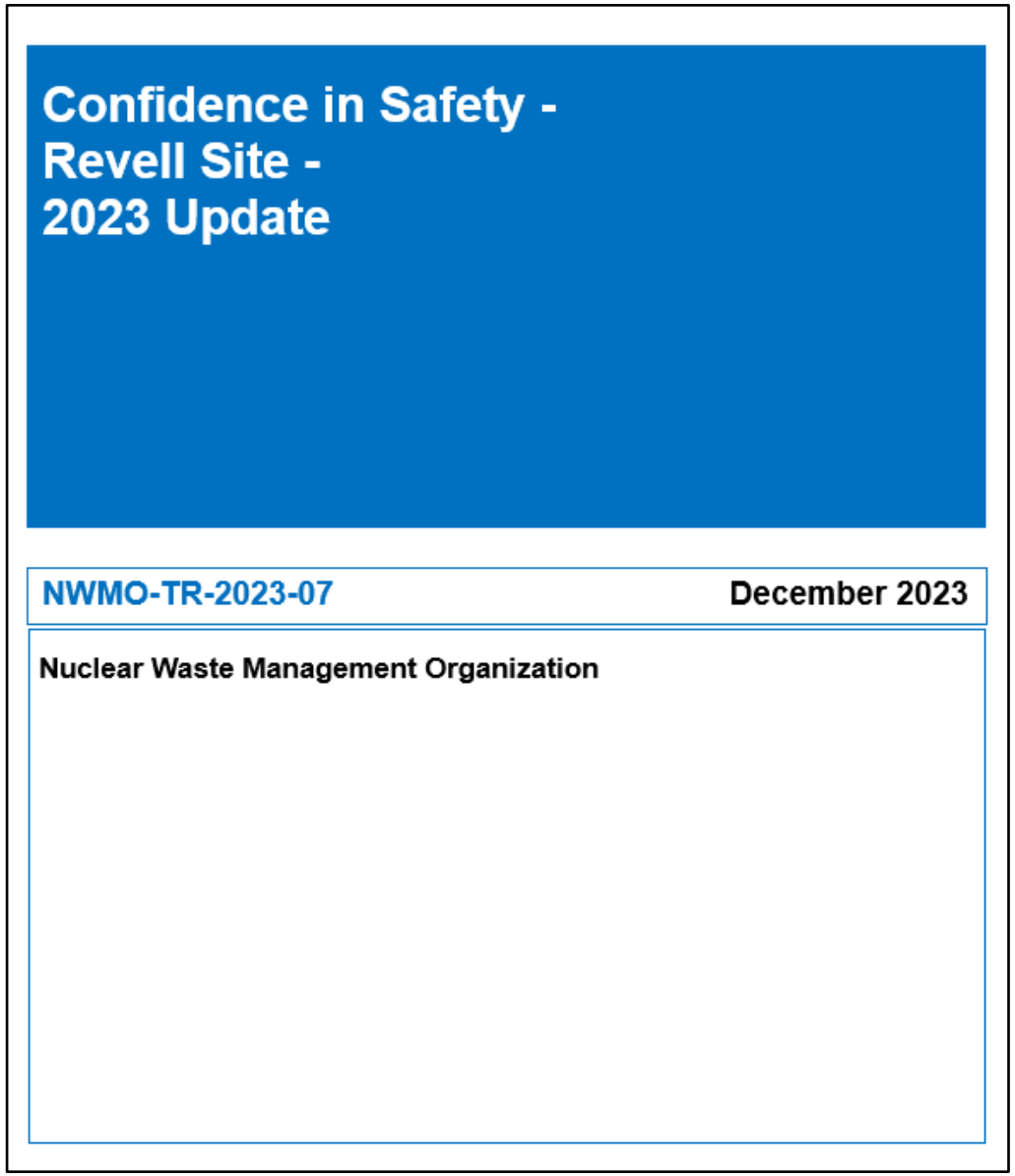
Proposed Swedish facility (Source: SKB)

Intact rock core from Revell site

Finland repository tunnel (granitic rock). Source:Posiva

Document findings in public-facing reports

- 2023 report supports and extends our confidence story from 2022
- Site suitability from a technical (geoscience, design, safety assessment) perspective
- Supported by more than 50 site-specific technical reports; posted on our external website
- Also based on the multiple barrier system, an internationally accepted approach.



Document findings in public-facing reports

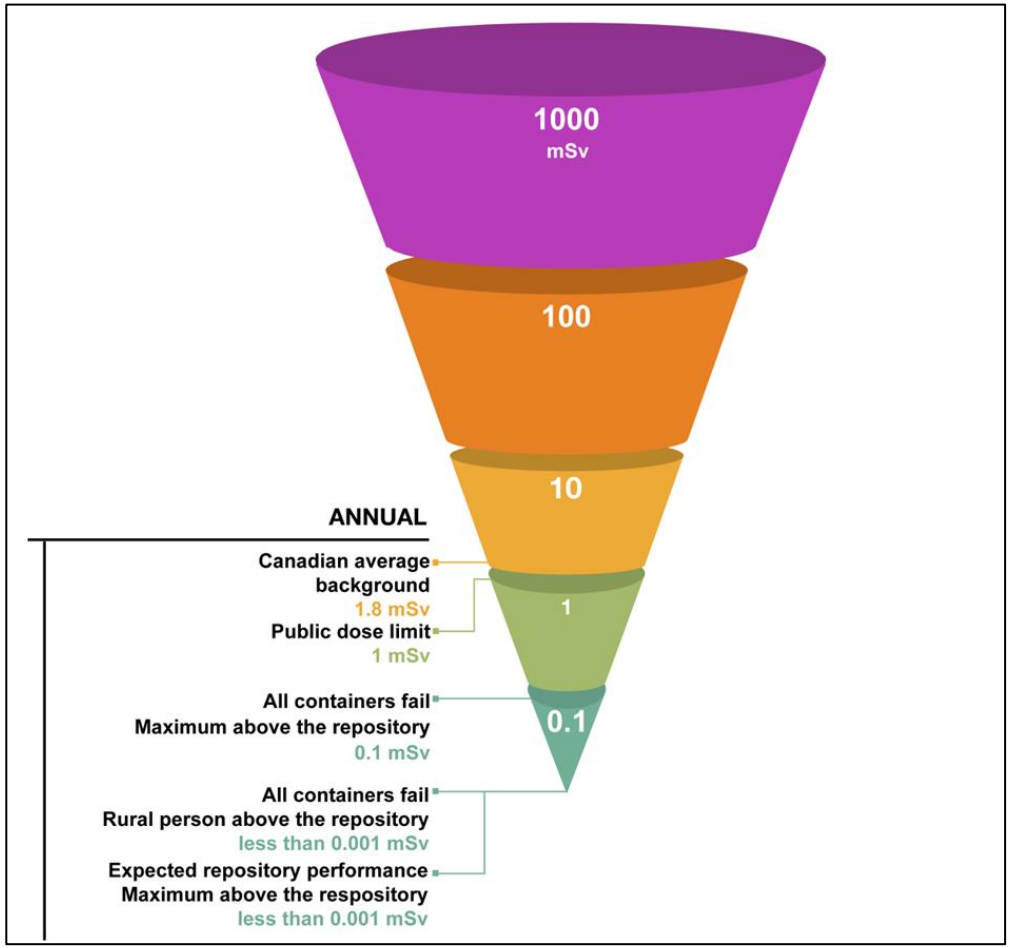
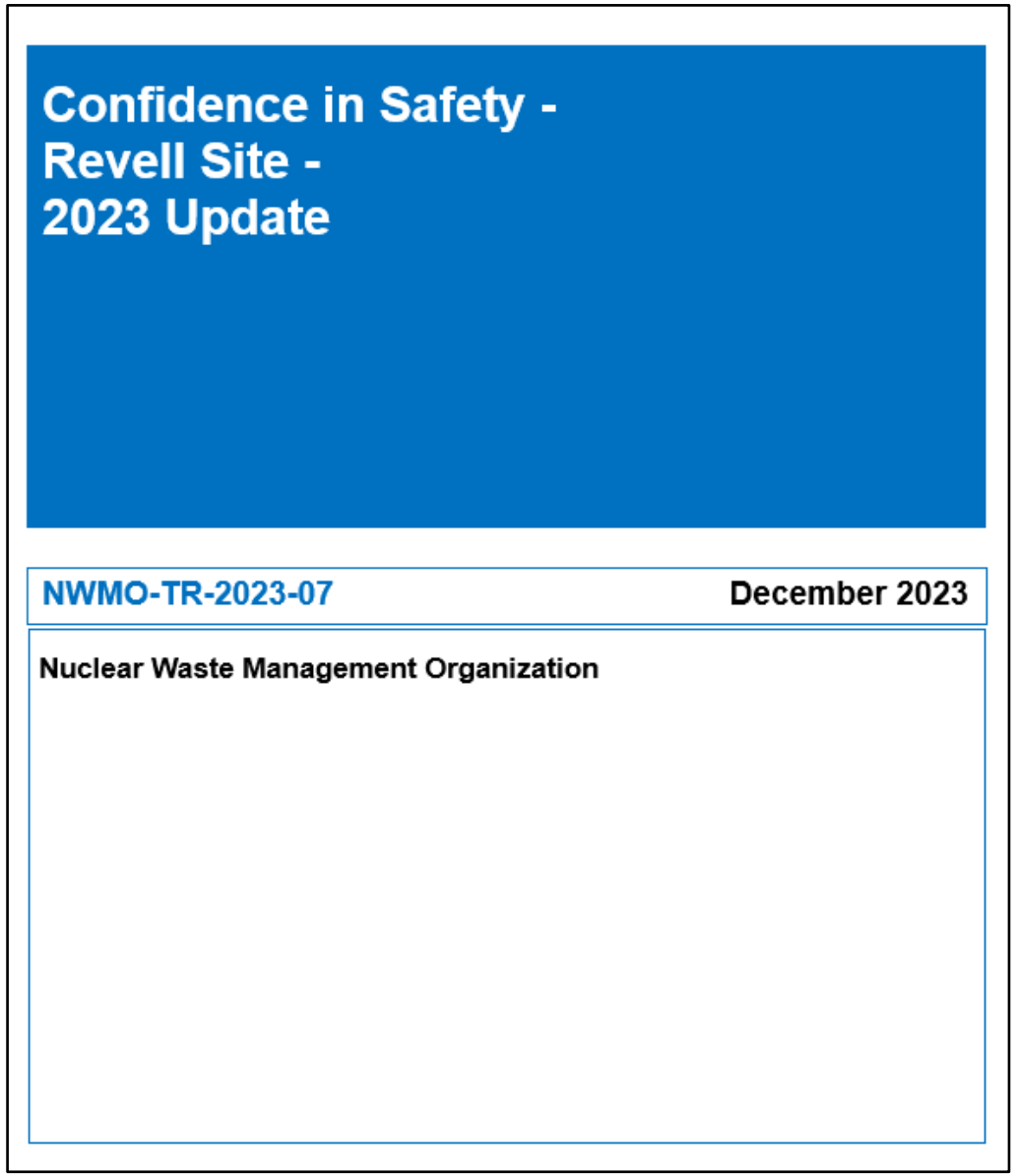


Illustration of potential post-closure peak dose in comparison with natural background and regulatory limits.



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