

# Review of Geophysical Methods to Support Evaluations of Potential Candidate Sites for a Used Nuclear Fuel Deep Geological Repository

G.W. Schneider<sup>1</sup>, S.J. Emsley<sup>1</sup>, M.E. Monier-Williams<sup>1</sup>, R.K. Davis<sup>1</sup>, F.L. Paillet<sup>2</sup>, R.M. Turpening<sup>3</sup> and S.J.Y. Sol<sup>1</sup>, A. Vorauer<sup>4</sup>

<sup>1</sup>Golder Associates Canada, UK, USA

<sup>2</sup>University of Arkansas

<sup>3</sup>Michigan Technical University

<sup>4</sup>Nuclear Waste Management Organization

## Introduction

The Nuclear Waste Management Organization (NWMO) is responsible for implementing Adaptive Phased Management (AMP), the approach selected by the Government of Canada for long-term management of used nuclear fuel waste generated by Canadian nuclear reactors. The ultimate objective of APM is centralized containment and isolation of used nuclear fuel in a deep geological repository in a suitable sedimentary or crystalline rock formation.

In 2008 and 2009, the NWMO commissioned a review of available satellite, airborne, surface and borehole based geophysical tools and techniques for screening and characterizing potential candidate repository sites, in order to develop readiness for site evaluation (NWMO 2008, NWMO 2009). The review looked at the state-of-the-science technologies, applicability, accuracy, limitations and constraints, and practices in similar investigations undertaken in Canada and other countries.

## Geophysical Methods Reviewed

A wide range of geophysical methods are applicable to site screening and characterization studies including satellite, airborne, ground and borehole methods. The following geophysical methods were reviewed.

### Satellite Surveys

- High resolution satellite imagery
- Synthetic Aperture Radar Interferometry (InSAR)
- Advanced Space-borne Thermal Emission and Reflection Radiometer (ASTER)

### Airborne Surveys

- Aerial photography
- Digital terrain mapping (Radar, LiDAR)
- Hyperspectral imaging
- Magnetism
- Radiometrics
- Electromagnetics
- Gravity

### Deep Ground-Based Surveys

- Seismic reflection (2D and 3D)
- Gravity
- Electromagnetics
- Magnetism

### Shallow Ground-Based Surveys

- Seismic refraction
- Electrical resistivity imaging (ERI)
- Ground penetrating radar (GPR)
- Frequency domain electromagnetics (FDEM)
- Spontaneous potential (SP)
- Induced polarization (IP)

## Borehole Methods

- Borehole orientation
- Normal electric
- Induction
- Natural gamma
- Spectral gamma
- Density
- Neutron
- Caliper
- Optical televiewer
- Acoustic televiewer
- Gravity
- Nuclear Magnetic Resonance (NMR)
- Fluid temperature and resistivity
- Impeller flow meter
- Heat pulse flow meter
- Electromagnetic flow meter
- Full waveform sonic
- Vertical Seismic Profile (VSP)
- Cross-hole seismic reflection
- Borehole radar
- Borehole TDEM
- Cross-hole EM

## Case Studies

Case study reviews provided good insight into how geophysical techniques were being applied in nuclear repository programmes in countries around the world, and in other heavy civil investigations. The review included the following repository sites, underground laboratories and heavy civil project sites:

### Crystalline Rock Environments

- Oskarshamn and Forsmark Sites, Sweden
- Olkiluoto Site - Granite, Finland
- Granitic Rock, Czech Republic
- Üveghuta Site, Hungary
- Water Tunnel No. 3, New York, USA
- Yucca Mountain, USA
- Sellafield Site, UK
- Mizunami / Shobasama Site, Japan
- AECL Underground Research Laboratory, Manitoba, Canada

### Sedimentary Rock Environments

- Zürcher Weinland Site, Switzerland
- Bure Site, France
- Michigan Technological University (MTU) Test Site, Michigan, USA
- Detroit River International Crossing (DRIC), Ontario, Canada

## Conclusions

Geophysics has played an integral part in the screening and characterization of both sedimentary and crystalline rock candidate sites in countries with nuclear programs that have adopted the Deep Geological Repository Concept. Geophysics provides important insight into rock stratigraphy, lithology, physical properties, structures, stresses, and hydrogeologic properties. Method selection is a function of the specific geology of the site and the questions that need to be answered to support geosphere model development.

## References

NWMO 2008. Review of Satellite, Airborne and Surface Based Geophysical Tools and Techniques for Screening Potential Nuclear Repository Candidate Sites. Prepared by: Golder Associates Ltd., NWMO TR-2008-15. (Available at [www.nwmo.ca](http://www.nwmo.ca))

NWMO 2009. Review of Borehole Based Geophysical Site Evaluation Tools and Techniques for Characterizing Potential Nuclear Repository Candidate Sites. Prepared by: Golder Associates Ltd., (in preparation)