Canada's Nuclear Regulator

Class IB Facilities

Guidance on Deep Geological Repository Site Characterization

REGDOC-1.2.1

February 2020

DRAFT

Canadian Nuclear Safety Commission
Commission canadienne de sûreté nucléaire

Canada

Guidance on Deep Geological Repository Site Characterization
Regulatory document REGDOC-1.2.1

Cat. No. NNNNN
ISBN NNNNN

Également publié en français sous le titre : Orientation sur la caractérisation des emplacements de dépôts géologiques en profondeur

Document availability
This document can be viewed on the CNSC website. To request a copy of the document in English or French, please contact:

Canadian Nuclear Safety Commission
280 Slater Street
P.O. Box 1046, Station B
Ottawa, Ontario K1P 5S9
CANADA

Tel.: 613-995-5894 or 1-800-668-5284 (in Canada only)
Fax: 613-995-5086
Email: cnsc.info.ccsn@canada.ca
Website: nuclearsafety.gc.ca
Facebook: facebook.com/CanadianNuclearSafetyCommission
YouTube: youtube.com/user/cnscccsn
Twitter: @CNSC_CCSN
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Publishing history
[Month year] Version x.0

Preface

This regulatory document is part of the CNSC's regulated facilities and activities series of regulatory documents. The full list of regulatory document series is included at the end of this document and can also be found on the CNSC's website.

Regulatory document REGDOC-1.2.1, *Guidance on Deep Geological Repository Site Characterization*, sets out guidance for the site characterization stage of the siting process for a deep geological repository (DGR) facility for radioactive waste. Information gathered for site characterization may be used in subsequent licence applications.

This document supersedes R-72, *Geological Considerations in Siting a Repository for Underground Disposal of High-Level Radioactive Waste*, published in September 1987.

For information on the implementation of regulatory documents and on the graded approach, see REGDOC-3.5.3, *Regulatory Fundamentals*.

The words "shall" and "must" are used to express requirements to be satisfied by the licensee or licence applicant. "Should" is used to express guidance or that which is advised. "May" is used to express an option or that which is advised or permissible within the limits of this regulatory document. "Can" is used to express possibility or capability.

Nothing contained in this document is to be construed as relieving any licensee from any other pertinent requirements. It is the licensee's responsibility to identify and comply with all applicable regulations and licence conditions.

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REGDOC-1.2.1, Guidance on Deep Geological Repository Site Characterization

1. Introduction

A deep geological repository (DGR) is an engineered facility where radioactive waste is emplaced in a deep, stable, geological formation designed to isolate and contain radioactive waste over the long term [1]. Site characterization involves detailed technical investigations to increase the state of knowledge about a particular site. Regional and site-specific information are used to gain an understanding of a potential site, and the features and processes that might affect the long-term performance of a DGR facility at that site. These processes involve different scientific disciplines (such as hydrogeology, rock mechanics and geochemistry) that are integrated and interpreted together.

1.1 Purpose

This regulatory document provides guidance for site characterization for a DGR facility for radioactive waste.

Site characterization information is integral to licence applications for DGR facilities. Site characterization information should be taken into account during the design of a DGR facility and re-evaluated over the lifecycle of the facility, which includes site preparation, construction, operation, decommissioning and closure.

1.2 Scope

This document describes the elements of a site characterization program for a DGR facility.

Note that this document does **not**:

- provide guidance on finding or selecting a site; site selection is not an activity regulated under the *Nuclear Safety and Control Act* (NSCA)
- apply to surface and near-surface waste management facilities, including waste from uranium mines and mills
- provide guidance on long-term waste management strategies
- provide requirements for safety analysis of the operational phase of DGR facilities
- provide requirements for a post-closure safety case for geological disposal
- provide guidance for environmental protection, including environmental assessment (see REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*)

In this document, the post-closure (or long-term) period is the period that follows the closure of a DGR facility [5, 8]. This long post-closure period is a feature of DGR projects, necessitating extensive geological site characterization activities (section 3 of this document) and a long-term safety case as outlined in REGDOC-2.11.1, *Waste Management, Volume III: Safety Case for Long-Term Radioactive Waste Management*.

The pre-closure period of a DGR encompasses site preparation, construction and operation of the DGR and the decommissioning of ancillary facilities.

1.3 Relevant legislation

The following provisions of the *Nuclear Safety and Control Act* (NSCA) and the regulations made under it are most relevant to this document:

- *NSCA*
- *Class I Nuclear Facilities Regulations*, paragraphs 4(a) and 4(c)

Other legislation relevant to this guide is as follows:

- *Impact Assessment Act*
- Provincial laws

2. Background

Site characterization data is used to evaluate the suitability of a possible site, inform the design of a DGR facility, and support the safety case for any potential DGR project. This information is necessary for detecting potential short- and long-term environmental impacts at various stages and for tracking what information is used (and how it is used) throughout the CNSC's licensing lifecycle for a DGR. Baseline data provides initial information for evaluating safety at the siting stage and during initial facility design, and also contributes to determining the effect of features, events and processes associated with the DGR system. Data needs include relevant regional- and site-scale information.

Early in the site selection process for a DGR facility, the project proponent should consider whether the characteristics of a site used for the DGR:

- could affect the environment
- could adversely affect an Indigenous group's potential or established Indigenous and/or treaty rights, such as the ability to hunt, trap, fish or gather, or conduct cultural ceremonies, per REGDOC-3.2.2, *Indigenous Engagement*

This information would be submitted with a licence application and feed into any impact assessment.

Early dialogue with the regulator for clarity on regulatory expectations and requirements is recommended. Included in this process is the identification of site characterization activities that may not require a licence from the CNSC. This can be formalized through a service arrangement between the regulator and the proponent.

2.1 Environmental reviews

The CNSC has the mandate to protect the environment. The CNSC assesses the environmental effects of all nuclear facilities or activities at every phase of their lifecycles, and requires that the environmental effects of all licensed activities be evaluated and considered when licensing decisions are made. Environmental reviews are based on the scale and complexity of the environmental risks associated with a nuclear facility or activity. Early in the process, CNSC staff determine which type of environmental review applies by reviewing the information provided by the applicant or licensee in their application and supporting documentation.

One form of environmental review is an impact assessment. Impact assessments are carried out in accordance with federal environmental legislation (that is, the *Impact Assessment Act* and its regulations). The impact assessment is led by the Impact Assessment Agency of Canada, with CNSC participation. An impact assessment decision must be rendered before a licensing decision can be made under the NSCA.

Site characterization information is an important consideration for all environmental reviews. The CNSC reviews this information during the assessment of all licence applications in the facility's lifecycle.

For more information on the CNSC's environmental review and licensing processes, see:

- REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*
- REGDOC-3.5.1, *Licensing Process for Class I Nuclear Facilities and Uranium Mines and Mills*

2.2 Public and Indigenous engagement

Potentially interested Indigenous groups should be engaged early during the site characterization phase in order to discuss project plans, gather Indigenous knowledge / land use information and address any concerns, as appropriate, early on in the site characterization and project development process.

Conducting engagement activities with the public and Indigenous groups early in the site characterization process is expected to lead to more effective and efficient consultation practices, strengthen relationships with Indigenous communities, assist the Crown in meeting its obligations regarding any potential duty to consult, and reduce the risk of delays in the regulatory review process.

Early in the site evaluation process, the applicant should develop and implement a public information and disclosure program, per REGDOC-3.2.1, *Public Information and Disclosure*. Furthermore, as set out in REGDOC-3.2.2, *Indigenous Engagement*, the applicant should identify and engage with potentially interested Indigenous groups. Information on these activities would be submitted to the CNSC as part of a licence application.

2.3 Overview of site characterization

Site characterization begins before the applicant submits a licence application to the CNSC and continues throughout the lifecycle of the DGR facility. The proponent will review and update this information, to reflect changes in the vicinity of the site and to incorporate new scientific data and knowledge. Characterization activities also support the engineering design.

Consideration of information from site characterization in all lifecycle phases will ensure that the facility's design basis and safety case remain current with changing environmental conditions or modifications to the facility itself.

The site characterization information is presented in this document as follows:

- **Site characterization:** Section 3 describes the application of site characterization information in all lifecycle phases, and describes activities to include in a site characterization program:

  - section 3.1 describes the role of site characterization in the CNSC's regulatory process
  - section 3.2 provides guidance on site characterization for the geological environment
  - section 3.3 provides guidance on site characterization for the surface environment
- **Human activities and land use:** Section 4 describes information gathering on past, present and potential future human activities at or near the site
- **Data acquisition and verification activities:** Section 5 describes information that would demonstrate, in a licence application, that the results of site characterization activities are accurate, complete, reproducible, traceable and verifiable
- **Verification and site characterization:** Section 6 provides information about potential approaches to verification of site characteristics

Appendix A describes the site selection process for a DGR facility, including the progress and importance of site characterization activities in the pre-application period.

3. Site Characterization for DGR Facilities

The characteristics of the host rock and geological system (that is, natural barriers) will be unique to the site chosen. The geological system refers to the characteristics influencing groundwater flow, rock mineralogy and structure, the location and properties of discontinuities, and geochemical processes. The characteristics of the surface environment provide baseline information for future environmental monitoring and potential mitigation activities.

Specific criteria provided for the collection of characterization data are not exhaustive. Guidance is presented in no specific order or priority; nor is it limited to the elements, approaches and techniques identified. Relative relevance of specific criteria will, in some cases, be site specific.

Note 1: Data and analysis results from site characterization may be used to satisfy information needed in subsequent licensing phases, as specified in the NSCA and associated regulations.

Note 2: The applicant should reject any unacceptable or inappropriate site before applying for a licence, without requiring CNSC involvement.

3.1 Role of site characterization in the CNSC regulatory process

Figure 1 shows where site characterization fits within the site selection process, and what role site characterization performs in the CNSC's regulatory process. Site characterization should be part of the information gathering and initial regulatory submission activities for the proposed DGR facility.

Site characterization data plays a role in detecting potential short- and long-term environmental impacts at various stages and for tracking the information that is used (and how it is used) throughout the licensing lifecycle.

The site characteristics are used to demonstrate how the radioactive waste would be adequately contained and isolated from the environment for an extended period known as the assessment time frame [4]. Information on the assessment time frame and the requirements for the long-term safety case needed for licensing are provided in REGDOC-2.11.1, *Waste Management, Volume III: Safety Case for Long-Term Radioactive Waste Management*. As such, site characterization is an essential component in site selection for gathering evidence on whether site

attributes will meet expectations as part of a post-closure safety case. Internationally, assessment time frames associated with DGRs span tens of thousands of years or more.

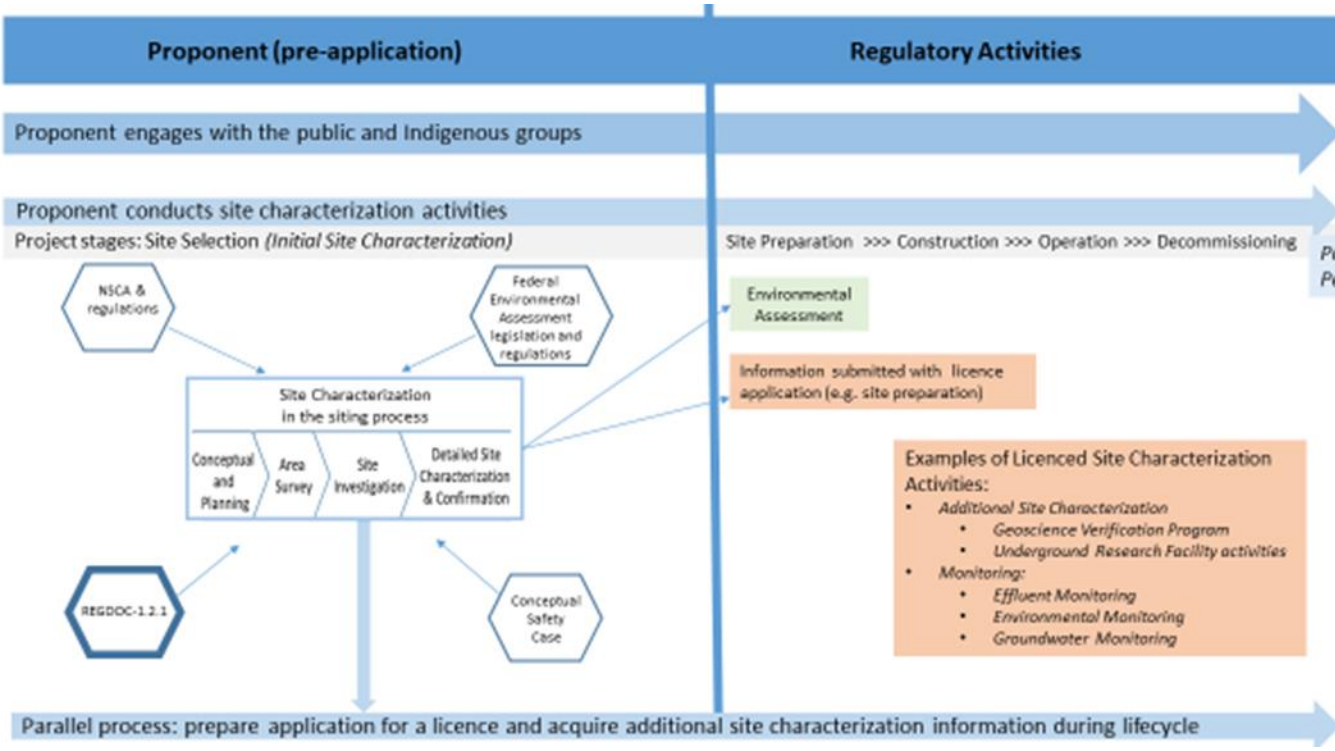
Examples of site characterization activities that would be licensed under the CNSC include:

- verification of information gathered and analyzed in earlier phases
- establishment of an adequate baseline for future monitoring
- information used in updates to the DGR facility post-closure safety case

Characterization activities that would continue until closure may be part of a geoscience verification plan.

Further information on the siting process for a DGR, including geological considerations, is available in appendix A and in international guidance documents [4].

Figure 1: Site characterization in the CNSC regulatory process



Site characterization data gathered during site selection should inform impact assessments and may be included in the initial licence application to the CNSC. Site characterization activities begin in a pre-application period, and would carry through to subsequent facility lifecycle phases.

3.2 Site characteristics I: Geological environment

The characteristics of the geological environment are necessary for assessing the post-closure safety of a DGR and should be considered in the engineering design. An investigation of a potential DGR site should evaluate a number of characteristics, including:

- containment and isolation characteristics of the host rock and geological system

- past and expected/projected future geological stability of the site, including the impacts of orogeny, seismicity, glaciation and volcanism
- extent of suitable host rock at the repository depth – is it sufficient?
- ability of the host rock and geological system to withstand stresses without significant breaching
- location relative to geological discontinuities
- demonstrated isolation of groundwater at selected repository depth from shallow groundwater systems
- characteristics favourable for limiting contaminant release and transport away from the DGR
- natural resource potential – is it low enough to limit the likelihood of inadvertent future human intrusion by subsequent generations of resource explorers?

For licence applications, an applicant should provide quantitative data in addition to qualitative descriptions where possible.

The following sections explain what characteristics an applicant should evaluate for the key geological factors that could be used to assess the suitability of a DGR site.

3.2.1 Geological setting

The geological characteristics, in combination with the engineered barriers and the design of the DGR, should indicate that the proposed DGR at the chosen site would remain safe for the entire period of concern (that is, including the post-closure period).

This information should include:

- tectonic setting
- structural geology
- stratigraphy
- chosen host rock type and extent
- fracture characteristics: frequency, orientation, mineralogy and spacing
- history of glacial cycles
- petrology
- geomechanical properties
- natural resource potential

Natural resource potential should be assessed quantitatively, and should include historical and current data.

3.2.2 Hydrogeological setting

Similar to the geological setting, hydrogeological setting characteristics should be used to evaluate site suitability. Information should include the following data:

- definition of regional hydrogeological regime and/or units
- regional and site-specific groundwater flow conditions (such as flow rate, flow direction, hydraulic heads and hydraulic gradients)
- hydrogeology of major rock units
- hydrogeological properties (such as porosity and hydraulic conductivity)
- recharge and discharge areas

- water budget
- location of existing and predicted future significant water-use areas (such as groundwater wells)

This data will help identify preferential pathways, velocities, residence times and other parameters.

3.2.3 Geochemistry

Together with the geological and hydrogeological features, the geochemical conditions provide essential information for predicting how contaminants could migrate from a DGR to the biosphere. Special emphasis should be placed on geochemical properties that can affect the migration of radionuclides in groundwater.

Information should include:

- mineralogy, including petrography
- groundwater/porewater geochemistry
- redox conditions
- movement of radionuclides (including, but not limited to, information on diffusion, solubility, speciation and retardation)
- movement of non-radioactive species (such as lead, arsenic, chromium and copper)
- geochemical impact of groundwater on engineered barriers
- microbiology
- potential for gas generation
- water–rock interaction

Any process that can be shown to demonstrate the potential for radionuclide migration or retardation from the DGR engineered facility through the geological environment should be documented.

3.2.4 Geological stability

The site should be located in a seismically stable region, demonstrated by an assessment of the potential for seismic or volcanic events. It should be demonstrated that any credible geological event that could occur during the assessment time frame would not impact the isolation and containment capability of a DGR.

The information that should be collected for the site and region includes:

- evidence of recent or historic active tectonic processes (neotectonics) – for example, information on Quaternary faulting and movement, soil liquefaction and volcanism
- record of seismicity at the site, such as documentation of historical earthquakes, their epicentres, magnitude and intensity, and recurrence (link with regional tectonics, structural geology)
- the effect of past glaciation events on the site as a basis for assessing the impact of future glacial events (in the post-closure period considered in the safety case, per REGDOC-2.11.1, *Waste Management, Volume III: Safety Case for Long-Term Radioactive Waste*

Management), linking hydrogeological, geochemical and geomechanical rock properties with glacial history

3.2.5 Geomechanical characteristics

Geomechanical characteristics should be collected and used to assess the pre-closure and long-term stability of the underground excavations, and the evolution of the damage zone around those excavations.

Geomechanical characteristics should include:

- the magnitude and orientation of the *in situ* stress
- the stress-strain-strength properties of the intact rock, fractures and rock mass
- the influence of time, temperature, scale, anisotropy, pore fluid pressure and other relevant factors on stress-strain-strength properties
- potential to withstand glacial events

3.3 Site characteristics II: Surface environment

Baseline environmental data is used to assess and predict the effects of a project on the environment. Surface processes at the site should be sufficiently characterized to ensure that natural hazard events, such as flooding, landslides and erosion, would not impact the ability of the radioactive waste disposal system to function safely.

3.3.1 Climate

The site area meteorological conditions should be adequately characterized and considered in the design of a DGR facility. Meteorological conditions should be determined from onsite and nearby meteorological stations where possible. This data should also be used as baseline data to evaluate the transport of potential airborne releases during the pre-closure period of the DGR facility. The applicant should justify the minimum meteorological data (that is, number of years of site-specific data) and demonstrate that it is commensurate with the type of project and the chosen site. Climate normal data (that is, 30 years of climate data) should also be included.

Specific information that should be collected includes:

- local and regional climatic history and expected future trends at both the regional and more global scale
- meteorological data, which should be collected at the site, local and regional scales to adequately capture future meteorological conditions that could occur over the time frames of the project
- regional and local precipitation characteristics
- extreme and average data on temperature, precipitation, wind speed and any other relevant phenomena on a regional basis
- wind and atmospheric dispersion characteristics for potential atmospheric releases
- potential for rare and extreme weather phenomena, such as hurricanes, tornadoes and severe winter storms
- ground frost and snow cover
- evapotranspiration (that is, evaporation and transpiration from soils, water bodies and plants)

- ice dynamics on lakes and streams
- air quality

The potential for climate change to impact processes relevant to the characteristics listed above over the lifecycle of the project should be considered.

3.3.2 Aquatic and terrestrial environment

The ecosystem components should be characterized in sufficient detail to enable the assessment of their importance, potential interaction with the project, and the potential for environmental effects arising from the project activities.

The elements of the aquatic ecology that should be characterized in the area of interest include:

- surface water characteristics – physical, chemical and biological properties
- sediment characteristics – physical, chemical and biological properties
- phytoplankton communities
- aquatic macrophytes
- zooplankton communities
- benthic macroinvertebrates
- fish
- fish habitat
- species designated as “at risk”

The elements of the terrestrial ecology that should be characterized in the area of interest include:

- soil quality
- vegetation
- wildlife
- terrestrial habitat
- species designated as “at risk”

The level of detail in the description of each of the above components should be in proportion to the potential for interactions with the DGR (more interaction means more detail).

3.3.3 Surface water hydrology

The drainage systems in the area should be assessed, to determine the nature of site drainage during the pre-closure DGR period. The importance of this information for a specific site, including the detail of information needed, should be assessed in a site-specific context. Stream, lake, pond and wetland networks in the vicinity of the planned facility should be characterized to evaluate potential for flooding, erosion, sediment transport and associated consequences.

Information that should be collected and evaluated includes:

- topography of the site and drainage features, including contributing drainage basin limits (extent, shape)
- regional and local precipitation characteristics, including extreme events
- size and location of surface water bodies
- gradient of the land surface

- density of the drainage network
- slope of the major stream channels
- identification and characterization of groundwater recharge areas and discharge areas (including receiving water bodies)
- drainage basins' water balance
- water table characteristics and seasonality
- magnitude and frequency of floods in the region

Flood-causing mechanisms that should be considered include:

- local intense precipitation
- flooding
  - in rivers and streams
  - from upstream dam breaches or failures
  - from storm surges or seiches
  - from tsunamis, tidal and wind waves
  - from snow-melting and ice-induced events
  - from channel diversions toward the site

The potential for climate change to impact processes relevant for the characteristics listed above over the lifecycle of the project should be considered.

3.3.4 Geomorphology characterization

The existing geomorphology of a site will permit an understanding of the Quaternary geological history of an area relevant for siting a DGR. It will also contribute to the geotechnical characterization. Characterization includes:

- distribution of landforms and thickness of surficial material (depth to bedrock)
- documentation of surface deposits and any existing or potential aggregate resources
- Quaternary geological history

3.3.5 Geotechnical characterization of surficial deposits

Geotechnical characterization of surficial deposits is important, as the integrity of the surface infrastructure could be affected by geotechnical properties of overburden materials during the pre-closure period of a DGR facility. Areas of concern include slope stability, excavation activities, physical stability and degradation of material stockpiles, stability of facility foundations, quality of human-made barriers constructed using overburden or other materials, waste settlement, settlement and damage of the facility covers, or any issue that could cause water infiltration and contaminant migration.

Geotechnical studies should include standard geotechnical sampling, field investigations and laboratory studies to assess:

- past occurrence of landslides and other potentially unstable slopes in the area
- the soil's physical and index properties (typically grain size, plasticity, dispersion and cohesive properties)
- shear strength parameters

- bearing capacity of foundation material
- liquefaction potential of loose granular material
- compaction properties
- hydraulic conductivity
- other site or facility design-specific properties

4. Human Activities and Land Use

Information on past, present and potential future human activities at or near the site should be collected, and the likelihood of whether these activities could have an impact should be assessed.

To limit adverse impacts on human activities and land use, the following information should be considered:

- valuable natural resources (such as groundwater, minerals, surface water or petroleum)
- potential for competing land-use activities at the proposed site; surface water use (such as access, recreation or hydroelectricity generation)
- Indigenous knowledge and historic and current land use by Indigenous communities and the public
- current and historical mineral exploration and mining activities – records of boreholes, shafts and other features or activities that could represent or cause potential instabilities or radionuclide migration pathways (such as fracking)
- potential impact of climate change

5. Data Acquisition and Verification Activities

The proponent should demonstrate in their licence application that the results of site characterization activities are accurate, complete, reproducible, traceable and verifiable.

5.1 Management system

In accordance with the *General Nuclear Safety and Control Regulations*, section 3(1)(k), the licence applicant is expected to describe the organizational management structure, including the internal allocation of functions, responsibilities and authority. Section 3(d) of the *Class I Nuclear Facilities Regulations* specifies that the applicant proposes the management system, including measures to promote and support safety culture for the activity to be licensed. The adequacy of the management system is assessed by CNSC staff. By implementing a management system, the organization would demonstrate compliance, ensure consistency in meeting requirements, set priorities and continuously improve the site characterization activities.

The licence applicant should develop and implement a management system for site characterization activities that are part of site selection, in accordance with the requirements specified in CSA N286-12, *Management System Requirements for Nuclear Facilities* [6], and aligned with CNSC REGDOC-2.1.1, *Management System*.

Topics covered under management system governance documentation are expected to include the generic and specific requirements for site characterization processes and practices.

5.2 Data management program

The integrity, accuracy and completeness of the information and data generated as a result of the site characterization activities are of utmost importance. The proponent should ensure the consistency and quality of the data used to develop the safety case submitted in support of any formal licence application.

The proponent should establish quality assurance and quality control programs to ensure high data quality and traceability. The programs should be focused on the production of documentary evidence to demonstrate that the required data quality has been achieved. Data should be collected, presented, stored and archived in a suitably standardized controlled fashion. Data should be compiled in a format that facilitates examination, comparison, identification of information gaps and independent review. For each site characterization component, the documentation should clearly indicate the properties being investigated, the data collection and investigation methods used, the results, and the associated assumptions and uncertainties.

The process of data evaluation and establishment of the site-related parameters involves technical and engineering analyses and judgments, which require extensive experience and knowledge. In many cases the parameters and analyses may not lend themselves to direct verifications through inspections and tests, or by other techniques that can be precisely identified and controlled. Therefore, these evaluations should be reviewed and verified by independent individuals or groups (that is, third-party reviews) that are separate from those who initially did the work. The reviews should be carried out at the different stages of the siting process in accordance with the work instructions and procedures.

5.3 Sampling and testing procedures

Site characterization is necessary, both to develop characterization activities, and to confirm, refine and adapt interpretations based on the initial data acquired from them. Activities that may serve to obtain the data necessary to guide later development phases and updates to safety assessments and the safety case include:

- geoscientific data compilation
- airborne geophysical (such as magnetic or gravity) surveys and seismic surveys
- shallow seismic techniques and drilling (which may be used to characterize the overburden)
- geological mapping
  - bedrock mapping
  - surficial mapping (that is, landforms, depth to bedrock, surface deposits or aggregate resources, Quaternary geological history)
- environmental characterization
- topographical mapping
- aerial photograph interpretation
- soil sampling to assess soil deposition and transportation processes
- geochemical rock property testing
- borehole drilling

5.3.1 Procedures for underground investigation using borehole drilling

Site characterization for DGRs involves the collection of reliable information on the subsurface conditions. In the pre-application stage (figure 1), much of the data is collected from the results of

various tests conducted in and between boreholes drilled specifically for this purpose. Accordingly, the site characterization program should describe the following:

- number, locations and types (that is, diamond drill vs. air percussion) of boreholes to be drilled on the site
- purpose of each borehole and its intended orientation, length and diameter
- types of drilling lubricants and drilling fluid tracers that will be used during drilling
- types of and schedule for borehole deviation monitoring to control orientation
- core recovery specifications, sampling intervals, and core logging and storage procedures, or chip sampling, logging and storage procedures
- number and types of physical tests to be done on core samples or chip samples
- schedule for drilling advance and for downtime for testing
- types of hydrogeologic testing (such as drill stem shut-in testing, pulse testing or tracer testing) to be performed during the drilling program
- groundwater samples that will be collected during drilling and the types of analyses of the groundwater that will be done
- record of the types of analysis performed, analytical instrumentation used, and the time between sampling and analysis
- borehole development and completion procedures (flushing, casing and grouting)
- borehole sealing procedures that will be followed should a borehole require abandonment

A borehole quality assurance and quality control program should be used to ensure that the objectives of the drilling program are achieved and controlled, and should include the following practices:

- maintenance of a drilling journal by a qualified drill-site geologist who records drilling and relevant drilling-related activities such as:
  - the cleaning of drill rods before drilling starts
  - surface casing installation and grouting procedures
  - drilling penetration rates
  - core recovery
  - presence of water-producing intervals and flow rates
  - amount of drilling fluid added and zones of water loss
  - measurements of tracer concentrations in drilling fluid and return water
  - additions of drilling lubricants
  - borehole development related to the removal of residual drill cuttings and drilling fluid, and core or chip sample information
- recording of static water-level information during shutdowns in drilling operations and the field chemistry of groundwater that is airlifted to the surface during the drilling of air percussion boreholes, and the procedures followed to collect and preserve such water samples
- post-drilling borehole surveys to confirm that the borehole has been drilled to the prescribed depth, diameter and orientation
- establishment of an electronic record that documents all borehole drilling activities and measurements

Other regulators will have jurisdiction over site characterization activities carried out before a site is selected and before an applicant engages in activities that would require a licence from the CNSC (see section 3.1). The applicant should conduct site characterization activities in consultation with the relevant regulatory bodies early in the process, to ensure that regulatory

expectations, permitting, licensing or other requirements are clearly understood, and that potential issues associated with data acceptance are identified and mitigated.

5.4 Integration and interpretation

Site characterization should lead to a detailed conceptual understanding of the site, through the analysis of a large number of physical and environmental components that interact with each other. This results in several independent systems of related components, where the components in each system can be interpreted to develop a conceptual site model. For example, the stratigraphy, lithology and spatial distribution of *in situ* stress can be interpreted to give a conceptual model of both the current and evolutionary structural geology of the site, while the distribution of mineralogy in the rock matrix and in fracture infilling can be interpreted to give a separate model of the site's geological evolution.

Different site models developed from different surveys and disciplines should be integrated into a single, consistent conceptual model of the site's geological and hydrogeological history, current conditions and expected (unperturbed) evolution.

The model of current conditions at a site provides the necessary information for design purposes. The history of the site should inform how the site has responded to past perturbations; extrapolating historical site information through to current site conditions can provide a model of how the site is expected to evolve in the future. Applying estimates of the perturbations imposed by the planned facility and the site response to past perturbations to the model of undisturbed site evolution should provide a model of the anticipated evolution of the site with the facility.

The applicant should amalgamate the results of site characterization integration and interpretation in a geosynthesis report, which would constitute an important supporting document to the post-closure safety case.

6. Facilities for Verification and Characterization Activities

An underground research facility (URF) is a facility typically constructed at a depth that provides a representative environment to acquire knowledge and provide training, to further characterize the geology, conduct experiments, test equipment and designs, and help demonstrate feasibility of a DGR.

Geoscientific characteristics of the subsurface cannot be obtained from surface-based activities (such as geophysical surveys, mapping, and deep borehole drilling), which are limited simply because they are surface-based observations of features that exist at depth. Therefore, verification and characterization activities (such as underground excavation and research) in a URF are considered as an international best practice for DGRs for high-level radioactive waste, including used nuclear fuel [8]. These activities reduce uncertainties, by providing more data to include in a safety case, and may be carried out at a generic and/or site-specific URF [2].

Setting up a URF is time consuming. There may be a significant time lapse between selection of a potential site and construction of a URF at that site. It also takes time to build research and support capacity by participating in URF activities in other countries. Therefore, a best practice is to plan for URF activities as early as possible in the siting process.

It is important for the licence applicant to discuss plans for verification with the CNSC at an early stage. This would include plans for a URF or similar facility. Early discussions help clarify the

regulatory approval process and identify site characterization activities related to verification. This dialogue is also necessary, in order to identify those site characterization activities that may be conducted before a CNSC licence may be obtained to prepare a site and/or licence to construct one.

Appendix A: Guidance on the Siting Process and Site Characterization

The process for selecting a site and the decision to choose a particular site are the responsibility of the licence applicant.

The International Atomic Energy Agency (IAEA) identifies four stages to the siting process for a DGR [4]:

1. conceptual and planning stage

2. area survey stage

3. site investigation stage

4. detailed site characterization and site confirmation stage

Site characterization begins at stage 1 during the investigation of a site and is expected to become more intensive as the siting process progresses through to confirmation of the site. The transition from one stage to the next is somewhat arbitrary owing to the inevitable overlap in siting activities. Characterization activities also support the engineering design.

Following confirmation of the site and the initial phases of licensing, characterization activities would be expected to continue through the various CNSC licencing phases – site preparation, construction and operational – should a project meet with regulatory approvals. This appendix provides information on site characterization during the siting process.

A.1 Conceptual and Planning stage

An overall plan for the site selection process is developed at this stage. Activities include desktop data compilation and interpretation. They include the identification of desirable features as a basis for the second stage, as well as the conceptualization of a generic facility design based on the type, volume and radionuclide content of the radioactive waste to be managed. (For guidance, see REGDOC-2.11.1, *Waste Management, Volume III: Safety Case for Long-Term Radioactive Waste Management* [5] and CSA N292.0-14, *General Principles for the Management of Radioactive Waste and Irradiated Fuel*). Site screening criteria should be developed for selecting or rejecting potential sites and, eventually, identifying a preferred site.

A.2 Survey Stage

The survey stage involves the screening of identified potential siting areas and regional geological mapping and other regional-scale characterization activities (such as airborne geophysical surveys). Engineering design may evolve based on acquired site information. The goal of activities carried out at the surveying stage is to inform the screening process, which may narrow down potential sites.

A.3 Site Characterization Stage

The site characterization stage involves extensive field work and laboratory study, usually to gather site-specific data on a range of site conditions, including a site's geology, geochemistry and geomechanical suitability.

Early-stage site characterization activities involve scientific studies and desktop data compilation work, and include activities such as geophysical surveys and borehole drilling, though such activities would stop short of breaking the ground to excavate a shaft.

A preliminary safety case (including long-term models of safety) should be completed at this time to test the site's suitability to host a DGR facility, as well as to guide further characterization and confirmation activities. These preliminary safety cases may also form part of a comparative analysis of remaining sites (if applicable), which would lead to the next stage of site confirmation, in which detailed, extensive work would focus on one or more sites.

A.4 Site Confirmation Stage

Site confirmation generally consists of detailed, extensive field and laboratory studies at the selected site. It is at this stage that it may necessary to evaluate whether sinking a shaft or constructing an underground research facility (URF) would obtain more information.

A post-closure safety case should be prepared based on all of the data gathered during prior siting stages and in combination with information such as geology and hydrogeology, and information about other barriers such as the engineered barrier system, canister design, and radioactive waste characteristics. This information may be used to develop the safety case that will be submitted in the initial licence application (that is, licence to prepare a site or combined licence to prepare a site and construct it).

Glossary

For definitions of terms used in this document, see REGDOC-3.6, *Glossary of CNSC Terminology*, which includes terms and definitions used in the *Nuclear Safety and Control Act* and the regulations made under it, and in CNSC regulatory documents and other publications. REGDOC-3.6 is provided for reference and information.

The following terms are either new terms being defined, or include revisions to the current definition for that term. Following public consultation, the final terms and definitions will be submitted for inclusion in the next version of REGDOC-3.6, *Glossary of CNSC Terminology*.

containment
The function of the barrier to prevent or control releases of radioactive or hazardous wastes. For deep geological disposal, this refers to the functions of both the natural barrier (such as the host rock) and the engineered barrier to limit radionuclide releases.

isolation
The physical separation of radioactive waste from people and the environment to make accessing the waste difficult. For deep geological disposal, isolation is provided mainly by the depth of the repository.

References

1. International Atomic Energy Agency (IAEA), *IAEA Safety Glossary: Terminology Used in Nuclear Safety and Radiation Protection*, 2007 Edition, Vienna, 2007.

2. IAEA, IAEA Safety Standards Series, No. SSG-14, *Geological Disposal Facilities for Radioactive Waste*, Vienna, 2011.

3. Canadian Nuclear Safety Commission (CNSC), REGDOC-2.11.1, *Waste Management, Volume II: Assessing the Long Term Safety of Radioactive Waste Management*, Ottawa, 2018.

4. CNSC, REGDOC-2.9.1, *Environmental Protection: Environmental Principles, Assessments and Protection Measures*, Ottawa 2017.

5. CNSC, REGDOC-3.2.2, *Indigenous Engagement*, Ottawa, 2019.

6. CSA Group, CSA N286-12, *Management System Requirements for Nuclear Facilities*, 2012.

7. IAEA, IAEA Safety Standards Series, No. SSG-23, *The Safety Case and Safety Assessment for the Disposal of Radioactive Waste*, Specific Safety Guide, Vienna, 2012.

8. IAEA, IAEA Safety Standards Series, No. GSG-1, *Classification of Radioactive Waste*, Vienna, 2009.

9. IAEA, IAEA Safety Standards Series, No. SSR-5, *Disposal of Radioactive Waste*, Vienna, 2011.

Additional Information

The CNSC may recommend additional information on best practices and standards such as those published by CSA Group. With permission of the publisher, CSA Group, all nuclear-related CSA standards may be viewed at no cost through the CNSC web page "How to gain free access to all nuclear-related CSA standards".

The following documents provide additional information that may be relevant and useful for understanding the requirements and guidance provided in this regulatory document:

- Western European Nuclear Regulators' Association, *Report: Radioactive Waste Disposal Facilities Safety Reference Levels*, 2014.
- CSA Group, CSA N292.0-14, *General Principles for the Management of Radioactive Waste and Irradiated Fuel*, Mississauga, 2014.
- WM2015 Conference, March 15–19, 2015, *Need for and Use of Generic and Site-Specific Underground Research Laboratories to Support Siting, Design and Safety Assessment Developments – 15417*. Phoenix, Arizona, USA.

CNSC Regulatory Document Series

Facilities and activities within the nuclear sector in Canada are regulated by the CNSC. In addition to the *Nuclear Safety and Control Act* and associated regulations, these facilities and activities may also be required to comply with other regulatory instruments such as regulatory documents or standards.

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