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Deep Geological Repositories

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Explanatory Report for Guideline

ENSI-G03/e

Contents

1 Introduction

This guideline ENSI-G03 replaces guideline ENSI-G03, issued in 2009. It is based on the Nuclear Energy Act of 21 March 2003 (NEA; SR 732.1) and the Nuclear Energy Ordinance of 10 December 2004 (NEO; SR 732.11) and sets out the design principles for deep geological repositories according to Article 11 paragraph 3 of the NEO and the requirements for demonstrating operating and long-term safety.

2 Harmonisation with International Requirements

2.1 IAEA

Of the IAEA Safety Standards pertinent to the Requirements categories, the recommendations from the following document are relevant for guideline ENSI-G03:

IAEA Safety Standard SSR-5: Disposal of Radioactive Waste, 2011

Appendix 1 shows how these recommendations have been considered in Swiss legislation and guidelines.

2.2 WENRA

The Western European Nuclear Regulators Association (WENRA) has defined pan-European harmonised safety requirements (Safety Reference Levels, SRL).

The WENRA Safety Reference Levels from the report “Radioactive Waste Disposal Facilities Safety Reference, 22 December 2014” are relevant for guideline ENSI-G03.

Appendix 2 lists the relevant WENRA Safety Reference Levels and indicates which section of the guideline deals with them.

3 Layout of the Guideline

Section 1 comprises the introduction, which is the same for all ENSI guidelines.

Section 2 lists the legal foundations on which the guideline is based. ENSI is the regulatory authority in respect of nuclear safety and security (Article 70 paragraph 1 letter a of the NEA). As such, it is ENSI’s responsibility to issue guidelines within its regulatory areas. These clarify undefined legal concepts in the legal principles and ensure uniform practical implementation. ENSI does not require an explicit mandate in a particular ordinance to be able to issue guidelines. Nevertheless, various such mandates exist within the ordinances included in nuclear energy legislation.

Section 3 covers the presentation of the subject and scope of application.

Section 4 covers basic requirements concerning the protection objective for deep geological disposal and its implementation.

Section 5 relates to the design of a deep geological repository.

Section 6 deals with monitoring, the pilot facility and permanent marking.

Section 7 regulates activities in the deep geological repository relating to geological investigations for emplacement, backfilling and sealing, the possible retrieval of radioactive waste, and temporary closure during the operational phase up until closure of a deep geological repository.

Section 8 deals with civil engineering planning and the construction of underground structures, the associated surface facilities and near-surface access structures.

Section 9 covers with the safety case for the operational phase and the post-closure phase.

Section 10 deals with security and safeguards.

Section 11 relates to quality assurance and documentation.

Section 12 contains a list of references.

Appendix 1 defines terms which are incorporated in the ENSI glossary.

Appendix 2 gives an overview of the planning, construction, operation and closure procedure.

4 Explanations of Individual Sections of the Guideline

Re Section 3 “Subject and Scope”

According to Article 3 letters c and d of the NEA, a deep geological repository is a nuclear installation located deep underground, which, in accordance with Article 64 of the NEO, comprises the main facility, pilot facility and test areas. Pursuant to Article 49 paragraph 5 of the NEA, a nuclear installation also encompasses all exploitation and installation sites associated with its construction and operation, for example the surface facilities and near-surface access structures. The deep geological repository also includes sites for the recycling and deposition of excavated, extracted and demolition material, which are closely related to the project in terms of space and functionality.

The method and criteria by which sites for deep geological repositories are selected for all waste categories in Switzerland are included in the conceptual part of the Sectoral Plan for Deep Geological Repositories (SFOE: Sectoral Plan for Deep Geological Repositories – Conceptual part, revision of 30 November 2011). Therefore, the guideline does not contain any specific requirements for the selection of geological sites. ENSI has supplemented and clarified the safety specifications for stage 3 of the sectoral plan both for site comparison and for general

licence applications for the selected sites (ENSI 33/649: Details of the Safety Specifications for Stage 3 of the Sectoral Plan for Deep Geological Repositories, 2018).

The realisation of a deep geological repository is subject to a multi-stage licensing procedure (general licence, construction licence, operating licence, closure and release from nuclear energy legislation). Compliance with all statutory regulations and in particular with the requirements for nuclear safety and security has to be checked as part of this process. The Federal Council is responsible for granting the general licence and for determining that the repository is no longer subject to nuclear energy legislation, while the Federal Department of the Environment, Transport, Energy and Communications (DETEC) is responsible for the other licences. The authority managing the process (Swiss Federal Office of Energy, SFOE) is required to invite all the competent authorities to submit their views. The decision-making authority coordinates the various legal rules in formal and material terms. Revisions within the Federal Administration are governed by Articles 62a et seq. of the Government and Administration Organisation Act of 21 March 1997 (GAOA: SR 172.010).

The personnel of a deep geological repository are subject to the Ordinance on Qualifications required by Personnel in Nuclear Installations (NPQO; SR 732.143.1) and to guideline ENSI-B10.

Re Section 4 “Basic Requirements”

Re Section 4.1 “Protection Objective for Deep Geological Disposal”

Disposal of Radioactive waste should take place in a deep geological repository in accordance with Article 31 of the NEA. In this way the radioactive waste is isolated from the human environment. The long-term safety of the deep geological repository has to be ensured by means of a system of staged, passively functioning engineered and natural barriers (multiple barrier system, Article 11 paragraph 2 letter b of the NEO), whereby the terms barrier and safety barrier are used synonymously in guideline ENSI-G03.

Absolute containment of all radioactive substances over very long periods of time is impossible. The barrier system has to therefore be designed in such a way that the release of radionuclides through the engineered and natural barriers to the biosphere remains low and the protection of humans and the environment is ensured. This can be achieved by containing radioactive waste over a certain period of time, by retarding the release of radioactive substances from the waste matrix and by retaining radioactive substances inside the engineered and natural barriers.

The protection objective is in line with Article 4 of the NEA and the basic protection objective according to the IAEA’s Fundamental Safety Principles (2006). The basic protection objectives in Article 1 letter d of the DETEC Ordinance on Hazard Assumptions and Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2) apply to the operational phase.

Re Section 4.2 “Specific Design Principles for Deep Geological Disposal”

The principles for deep geological disposal are based on Principle 7 of IAEA Safety Standard SF-1 (2006) and the principles and requirements for the deep geological disposal of radioactive waste in IAEA Safety Standard SSR-5 (2011).

The guiding principle concerning the protection of humans, which was present in the previous version of this guideline, is no longer specified because it is covered by Articles 1 and 4 of the NEA and Section 4.3 of this guideline.

The former guiding principles concerning safety barriers and monitoring and retrieval are no longer specified in this section because their objectives are covered by Article 11 paragraph 2 of the NEO.

The former guiding principle on freedom from burdens is no longer specified because this principle is already part of the protection objective of the deep geological repository. Pursuant to Article 31 of the NEA, the obligation to manage and dispose of radioactive waste lies with the nuclear installation operators. Thus, the society that has benefited from the use of nuclear power is obliged to prepare and implement deep geological disposal to such an extent that unreasonable burdens are not inflicted on future generations. Preparations are documented in the waste disposal programme and in the cost study, and reviewed periodically.

The former guiding principle concerning natural resources is no longer specified in the guideline because the presence of workable raw materials and any conflicts of use are taken into account in the site selection procedure described in the Sectoral Plan for Deep Geological Repositories. This is in keeping with the need for sustainability because resources should remain accessible to future generations. The absence of natural resources of particular importance reduces the likelihood of inadvertent human intrusion. Therefore, economic use of the underground area is not covered by the guideline.

The former guiding principle concerning optimisation is no longer specified in this section because it is covered by Section 4.4 of this guideline.

Re letter a: If no further measures are necessary to ensure long-term safety after orderly closure of a deep geological repository, only minor obligations will arise for future generations (for example, to maintain awareness of the repository location for as long as possible). Passively functioning engineered and natural barriers ensure that no further active human intervention is needed and that long-term safety is ensured even when there is no stable society.

Re letter b: Protection against a risk arising from ionising radiation is required irrespective of the current existing national borders. This is in line with today’s understanding of responsibility. The importance of state borders is put into perspective by the fact that the effects of a closed deep geological repository on the human environment may only occur after a long time. Such time periods may exceed the duration of national borders many times over.

Re letter c: Ethical considerations (refer to Susanne Brauer: Schutzziele als ethische Fragen (Protection objectives as ethical questions), report commissioned by the Swiss Federal Office

of Energy, 2018) form the basis of an obligation to protect future generations. The policy is based on the principle that each generation, whether today or in the future, has the same right to protection against a hazard caused by ionising radiation. It is not possible to make reliable statements about the distant future of humanity. This applies in particular to human lifestyles, nutrition and the sensitivity of humans to ambient radiation. Based on this fundamental lack of knowledge of the sensitivity of the humans to be protected in the future, the same protection can only be implemented by ensuring that the containment effectiveness of a deep geological repository meets the same requirements both today and in the future. The current valid protection requirements form the benchmark for these requirements.

Re letter d: Protection of the environment includes protection of the natural basis for the existence of humans and wide-ranging protection of species (maintaining biodiversity) for other living beings. This is in line with international sustainability efforts (Report of the World Commission on Environment and Development: Our Common Future, 1987; Report of the United Nations Conference on Environment and Development, Rio de Janeiro, June 3, 1992 – Annex I, Rio Declaration on Environment and Development).

Internal discussions on how to protect all living organisms are still ongoing. The ICRP's efforts (The 2007 Recommendations of the International Commission on Radiological Protection, 2007) are focussed on reliably estimating the radiation effect on some typical life forms (Environmental Protection – the Concept and Use of Reference Animals and Plants, 2008). However, these do not make any specific recommendations regarding dose limits. The guideline is therefore based on the previous assumption that species are protected when the necessary precautions for the individual protection of humans have been taken. International developments in the field of environmental protection will continue to be pursued (ENSI 33/606: Overview of International Status of considering Radiological Protection of Non-Human Biota in the context of deep Geological Disposal of Radioactive Waste, 2018).

Re Section 4.3 "Protection Criteria"

Re Section 4.3.1 "Operational Phase"

The radiological protection criteria for the operational phase of a deep geological repository are based on the Radiological Protection Act of 22 March 1991 (RPA; SR 814.50) and the Radiological Protection Ordinance of 26 April 2017 (RPO; SR 814.501). They therefore comply with the requirements applicable to all radiation sources, including nuclear power plants and interim storage facilities. Constraints are regulated by guideline ENSI-G15 (e.g. short-term release limits) and derived from the radiation protection objectives concerning limiting (or limitation) and optimising radiation exposure. The protection criterion in Section 4.3.1 letter a of this guideline ENSI-G03 corresponds to the constraint in Section 4.3.1 letter b of guideline ENSI-G15. Measures to comply with the protection criteria are covered specifically by guideline ENSI-G12, which is expected to come into force in 2021. The draft guideline for the public

hearing is available at: https://www.ensi.ch/de/dokumente/entwurf-ensi-g12-anlageinterner-strahlenschutz/

Re letter a: As part of the general licence, the licensing authority shall establish a source-related dose constraint in accordance with guideline ENSI-G15. When applying for a general licence, the applicant should therefore submit a substantiated proposal for the source-related dose constraint (Article 7 of the RPO), based on its dose estimates, which takes into account the radiation protection principles of limitation and optimisation.

Re Section 4.3.2 “Post-Closure Phase”

Re letter a: The objective of deep geological disposal is to ensure permanent protection of humans and the environment. Protection criteria for the post-closure phase are intended to demonstrate permanent protection. A deep geological repository is so designed in accordance with paragraph 2.15 letter b of IAEA Safety Standard SSR-5 such that the individual dose resulting from possible natural processes remains less than 0.3 mSv per year or such that the resulting risk of radiation-induced cancer mortality or the risk of serious radiation-induced hereditary effects does not exceed 10^{-5} per year.

When applying the risk constraint based on paragraph 2.15 letter b of IAEA Safety Standard SSR-5, the probability of occurrence is determined and justified for the individual scenarios considered. Scenarios are possible variants for changes in the waste, engineered and natural barriers, the biosphere and human lifestyles under the influence of assumed features, events and processes (FEPs). The scenarios and probabilities of occurrence are determined for the safety assessment as described in Section 9.3.1. Simplifications to allow similar scenarios to be grouped together are permitted to prevent the scenarios being classified in too much detail (see paragraph 5.45 of IAEA Safety Standard SSG-23).

The resulting annual individual dose in the reference year is determined for an assumed scenario for changes in a deep geological repository. This annual dose is multiplied by the probability of occurrence of the scenario and a conversion factor used to determine the associated annual radiation-induced cancer mortality risk or the risk of serious radiation-induced hereditary effects. This risk is then compared with the risk constraint for each scenario. A value of 0.05 per Sv is used as the conversion factor. This value corresponds to the "approximated overall fatal risk coefficient" from ICRP Report 103 (2007) and is used here both to calculate the radiation-induced cancer mortality risk and the risk of serious radiation-induced hereditary effects.

However, the ICRP (ICRP Report 122, 2013) points out that the effective dose loses its direct link to health impairments for future doses after several generations, given changes in society, human habits and characteristics. Moreover, in the distant future, changes in the biosphere in particular will be less predictable. The scientific basis for assessing health damage in the far distant future will therefore be uncertain and it may be inappropriate to apply strict numerical criteria. For very long-term periods, the ICRP recommends that dose and risk criteria be used to compare options rather than to assess health damage.

Re letter b: Due to uncertainty about how society will evolve in the future, it is not possible to make reliable statements about inadvertent human intrusion into a deep geological repository. For this reason, the corresponding criteria set out in paragraph 2.15 of IAEA Safety Standard SSR-5 are adopted.

Re letter c: The uncertainties associated with dose calculations can become so large that the criteria may no longer serve as a reasonable basis for decision-making. For this reason, guideline ENSI-G03 requires that, after the end of the assessment period, the radiological effects of a deep geological repository shall not be significantly higher than the current natural radiation exposure in Switzerland. Calculations of radiological effects for the distant future should not be understood as an effective radiation exposure forecast for a definable population group, rather as an indicator for estimating the risks of potential changes.

The FOPH makes the following statements about the mean natural radiation exposure of the Swiss population (FOPH: Radiation Protection and Monitoring of Radioactivity in Switzerland – Results 2017, Brochure issued by the Federal Office of Public Health, 2018): The radiation exposure of the population is determined from the radiation doses arising from natural and artificial radiation sources. The three main causes are radon in homes, medical diagnostics and natural radiation. The average “radon dose” for the Swiss population today amounts to about 3.2 mSv per year. The radon exposure of the population is not uniform. The dose due to medical applications (diagnostics) is equivalent to 1.4 mSv per person per year across the population as a whole. The dose due to terrestrial radiation (i.e. radiation from the earth and rock) accounts for an average of 0.35 mSv per year and depends on the composition of the underground area. The dose due to cosmic radiation averages about 0.4 mSv per year. Radionuclides also enter the human body via food, resulting in doses of around 0.35 mSv. In addition to the radiation doses mentioned above, radiation exposure due to nuclear power plants, industry, research, medicine, consumer goods and daily objects, plus artificial radioisotopes in the environment, make a small contribution of no more than 0.1 mSv per year.

In total, the current average radiation exposure of the Swiss population is 5.8 mSv per year.

Re Section 4.4 “Safety Optimisation”

Re letter a: IAEA Safety Standard SSR-5 and the ICRP state that there is a duty of optimisation for a deep geological repository. Optimisation of operational safety is based on Article 4 of the RPO. The long-term safety of a deep geological repository is optimised using a step-by-step procedure based on recommendations contained in IAEA Safety Standard SSG-23.

Re letter b: This refers in particular to decisions that may have an influence on long-term safety. The underlying considerations should be documented (see Section 11). Due to the different requirements for operational and long-term safety of the deep geological repository, these may even contradict each other. The considerations therefore include a case-by-case assessment of what is favourable for safety overall. Where necessary, qualitative aspects may also be supported by numerical calculations.

Re letter c: The guideline sets out specific requirements for the effectiveness of the multiple barrier system as a whole with the aim of meeting the protection criteria. Even if the limits specified in the protection criteria are met, the radiological effects of a deep geological repository have to be reduced by means of suitable measures during planning, construction and operation as far as is possible and reasonable according to the state of the art of science and technology.

Re letter e: As a safety-enhancing measure, the design of the disposal canisters is required to completely contain high-level waste for a period of at least one thousand years. The containment period is derived from the decay of radiotoxicity and the heat output of the high-level waste during the first thousand years. During the full containment period, processes such as saturation of the backfill and changes in pressure and temperature over time in the near vicinity of the emplaced waste will approach equilibrium conditions. This will reduce the impairment of the geological environment caused by the emplacement, which will increase the robustness of the subsequent basic assumptions used for safety considerations. The length of time the disposal canisters are to be contained under deep geological repository conditions has to be demonstrated by the waste producers based on the state of the art of science and technology. The failure rate of the canisters and the extent to which this is dependent on time should be investigated.

Re Section 5 “Design”

The principles of nuclear safety and security as specified in nuclear energy legislation (Articles 4 and 5 of the NEA, Articles 7 to 11 of the NEO) shall apply.

Re Section 5.1 “Basic Requirements”

Basic requirements – i.e. requirements that apply both to the surface facility and auxiliary access facilities and to the underground facilities of a deep geological repository – include radiation protection (including radiological monitoring of exhaust air and wastewater as well as the treatment of radioactive waste resulting from operation), fire and lightning protection, long-term safety and the avoidance of criticality. This guideline addresses aspects relating to escape and rescue routes, criticality and long-term safety only as far as they are not covered by other guidelines.

Re letter a number 1: The necessary radiation protection and monitoring measures are regulated in the relevant ordinances and guidelines. These include in particular the RPO, the Ordinance on the Handling of Radioactive Materials of 26 April 2017 (SR 814.554) and the Dosimetry Ordinance of 26 April 2017 (SR 814.501.43) as well as guidelines ENSI-G05, ENSI-G12, ENSI-G13, ENSI-B04 and ENSI-B05.

The requirements set out in these documents include the following:

- The zoning concept for the operational radiation protection of the entire facility has to be defined for the duration of the operational phase. The zoning

concept defines the classification of the various areas of the deep geological repository as well as the associated surface facility and auxiliary access facilities in supervised and controlled areas (controlled zones) in accordance with Articles 80 and 85 of the RPO, and in types of working areas described in Article 81 of the RPO and types of zones and areas defined in Article 82 of the RPO.

- Waste and wastewater that cannot be guaranteed to be free of contamination has to be collected and disposed of in a controlled manner by appropriate systems. This applies in particular to waste and wastewater that is generated in the controlled zone of the surface facility or as a result of accidents and measures taken to resolve such accidents.
- Measures have to be taken to ensure that airborne radioactive substances cannot escape in an uncontrolled manner from areas in which radioactive substances are handled. This applies, for example, to the repackaging of radioactive material in the surface facility, the cleaning of transport and storage casks or to accidents.
- Specific filtering and retention devices in the ventilation system to limit the possible release of radioactive substances into the exhaust air.

Re letter a number 2: The requirements for organisational, structural, technical and defensive fire protection are based on cantonal and federal regulations (including the Swiss Fire Safety Regulations issued by the Association of Cantonal Fire Insurers, technical guidelines issued by the Association of Swiss Installers of Safety Systems) and guideline HSK-R-50.

Re letter b: The safety classification of mechanical and electrical equipment into safety and earthquake classes according to the criteria specified in Annex 4, No. 3 of the NEO and the resulting classification of structures into structure classes leads to further requirements for the design of the structures. The relevant standards of the Swiss Association of Engineers and Architects (SIA) have also to be considered with respect to these requirements.

Re letter c: The requirements for escape and rescue routes are regulated in guideline ENSI-B12, but these requirements are not applicable in all areas of escape and rescue routes in underground facilities (e.g. length of escape routes). For this reason, measures deviating from the guidelines should be described in an escape and rescue concept, demonstrating how this ensures that safety is still guaranteed. The submitted fire protection, escape and rescue concepts are reviewed by ENSI in consultation with other regulatory authorities and external fire protection experts. ENSI, as lead regulator, is responsible for appointing the other authorities and experts in time and in accordance with the submitted documents.

Re letter d: Changes and developments that could lead to an increase in reactivity after the closure of the deep geological repository may, for example, include corrosion of the fuel elements and disposal canisters, consolidation of the host rock or ingress of water into the emplacement cavern. Possible measures for avoiding criticality after closure may, for example,

include limiting the fuel per disposal canister and ensuring that the disposal canisters are arranged appropriately in the deep geological repository. With regard to the condition of the fuel elements during the operational phase, the geometry (form and location) and material properties of the fuel elements, as required in order to control reactivity, have to comply with the requirements of guideline ENSI-G20, Section 6.1 letter a number 1. Criticality safety has to be demonstrated in the safety case for both the operational phase and the post-closure phase. Proof of criticality safety for the operational phase is required by the DETEC Ordinance on Hazard Assumptions and Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2) and guideline ENSI-A05, for example. DIN Standard 25472 shall be considered for the period after closure of the deep geological repository.

Re letter e: If, despite any changes, long-term safety is maintained due to the interaction of all barriers, there is no impairment.

Re Section 5.2 “Additional Requirements”

Re Section 5.2.1 “Surface Facility and Auxiliary Access Facilities”

The external and internal accidents to be considered are covered in Article 8 of the NEO. The requirements of the DETEC Ordinance on Hazard Assumptions and Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2) apply when demonstrating sufficient protection against aircraft crash scenarios.

Re letter a: This requirement applies in particular to sections of the access structures close to the surface, as these are routed through water-carrying loose rocks.

Re letter b: The repackaging cell for high level waste (HLW) is the part of the encapsulation plant in which the spent fuel elements are repacked from the transport and storage casks (T/S casks) to the disposal canisters and the disposal canisters are welded. The repackaging cell therefore has higher requirements than other parts of the encapsulation plant.

Re c: The required capacity results from the operational requirements and relates, amongst other things, to the size of the buffer facilities or the number of docking points for T/S casks and disposal canisters on the repackaging cell. In addition, it may be necessary to maintain emplacement operation even if, for example, unforeseen repair work is required in the repackaging cell or contaminated parts of the facility cannot be used on a temporary basis after an accident.

Re letter d: During long dry storage of spent fuel, damage to the fuel elements due to fatigue cannot be ruled out. The condition of the fuel elements will only be visible once the T/S casks have been opened in the repackaging cell. For this reason, equipment has also to be available to allow the repacking of damaged fuel elements to disposal canisters if necessary.

Re Section 5.2.2 “Underground Structures”

Re letter a: The long-term safety of a deep geological repository is based on the containment and the retention of radionuclides to protect humans and the environment against dangers arising from ionising radiation. This is achieved by a system of engineered and natural barriers. Requirement 16 (Design of a disposal facility) of IAEA Safety Standard SSR-5 recommends that a deep geological repository, with its engineered barriers, be designed in such a way that it does not cause unacceptable long-term disturbance of the site, is itself protected by the site, meets the safety functions and has properties that complement the natural barriers.

Requirement 7 (Multiple safety functions) considers the main safety functions. A safety function is a function that is responsible for meeting safety-relevant requirements in a deep geological repository or a component of a deep geological repository. This can be achieved by a physical or chemical property or a process that contributes to containment and retention (e.g. impermeability to water, limited corrosion of waste canisters, low waste leach rate and solubility, retardation of radionuclide migration).

The safety case highlights the safety functions of the individual barriers, components of the deep geological repository and how they interact in the deep geological repository system (see Section 9.3). The safety case also includes the periods over which the individual barriers should fulfil their tasks and safety functions.

In accordance with Requirement 9, preservation of the natural barrier is of great importance because it is mainly this barrier that protects the deep geological repository against external influences. Due to the long periods of time, the geosphere is of particular importance. It has therefore to be chosen in such a way that it can provide the necessary protection for the required periods.

Re letter b: According to Article 11 of the NEO, long-term safety has to be ensured by staged, passive safety barriers (multiple barrier system). If a barrier only partially fulfils its function, further, different types of barriers will ensure the safety of the deep geological repository. Long-term safety therefore depends on the various, different barriers, each of which fulfils specific safety functions over different periods of time. Passive functioning means that no maintenance of the barriers is necessary after closure of the repository. In accordance with Article 11 paragraph 1 a of the NEO, suitable host rock has to have a sufficient extent.

Re letter c: There will always be changes to the barriers. The barriers lose their safety functions after a certain period of time. If the safety functions of the respective barrier are maintained within the planned period in spite of the change, there is no impairment of the barrier.

Re letter c number 1: The thermal put from heat-producing waste can, for example, affect sorption and swelling capacity and geomechanical behaviour of the engineered and natural barriers, self-sealing in the host rock, chemical interactions or gas transport.

Re letter c number 2: Gas formation due to metal corrosion or the degradation of organic substances from the emplaced waste, the canisters and the materials used for the lining of the emplacement drifts may cause a build-up in gas pressure. Technical measures such as waste

treatment, increasing the emplacement volume in the deep geological repository, selecting an appropriate distance between the emplacement drifts and/or the disposal canisters, and suitable backfilling and sealing materials can be used to demonstrate how excessive pressure build-up can be avoided.

Re letter c number 3: The materials used have to be suitable for the expected repository conditions over long periods of time, including chemical and thermal conditions, and for requirements of the long-term safety. It has to be taken into account as well that chemical reactions can be accelerated by microorganisms.

Re letter e: This requirement relates to the emplacement of different types of waste, which may interact negatively with each other. Such interaction can be prevented, for example, by adequate spatial separation. Separation is sufficient if no significant impairment of operational and long-term safety is to be expected. The separation of HLW and L/ILW repositories in the case of a combined repository is already covered in the specifications for stage 3 (ENSI 33/649, Section 4.6).

Re letter f: This separation is specifically intended to meet the radiation protection requirements. If the waste producers can prove that separate ventilation is not required for safety and radiation protection reasons (for example because contamination in the emplacement areas and the dispersal of airborne radioactivity can be ruled out in the event of a fire), separate ventilation systems are not required. The effects of construction activities in areas where radioactive waste is handled, such as heavy dust loads, should be prevented as far as possible by appropriate measures (e.g. directed or separate ventilation air flows).

Re letter g: Negative effects in the deep geological repository may occur, for example, due to underground water ingress, a rockfall or earthquakes. Such hazards caused by the rock mass are considered part of the safety case by identifying an overall facility-specific spectrum of potential initiating events for the safety assessments. In addition to the initiating events described in Article 8 paragraphs 2 and 3 of the NEO, Articles 4 and 5 of the DETEC Ordinance on Hazard Assumptions and the Evaluation of Protection against Accidents in Nuclear Installations, 17 June 2009 (SR 732.112.2) and guideline ENSI-A05, Section 4.5.1 a and b and Section 4.6.1, this also includes hazards and hazard scenarios caused by the rock mass, as listed by way of example in standard SIA 199 (Annex E). Deterministic and probabilistic methods can be used to determine the overall facility-specific event spectrum, taking into account national and international findings.

Re Section 6 “Monitoring, Pilot Facility and Marking”

Re Section 6.1 “Monitoring”

Monitoring implies continuous or periodic observation of properties or measurement of parameters over long periods of time. Monitoring of a deep geological repository covers all realisation phases and comprises different aspects (see b). Monitoring has to be adapted in a manner

appropriate to the respective phase for each monitoring aspect. In this case, the transition from the monitoring concept via the monitoring programme to the monitoring process itself is subject-specific, gradual and level-appropriate. For example, certain baseline measurements, such as seismic monitoring, begin even before the general licence application. In accordance with the ENSI specifications for stage 3 of the Sectoral Plan for Deep Geological Repositories, an integral monitoring concept has to be submitted with the general licence application, covering all realisation phases of a deep geological repository and including relevant monitoring aspects (e.g. baseline measurements, environmental monitoring, observations in the deep geological repository).

The operator of a deep geological repository is required to clarify non-radiological effects of deep geological disposal. This is subject to environmental protection legislation and to the specifications of the authorities responsible for environmental aspects. This clarification lies outside the scope of guideline ENSI-G03. However, the procedures described in guideline ENSI-G03 and IAEA Safety Standard SSG-23 may also be useful when assessing risks due to non-radioactive waste and when optimising protection and safety in the light of all potential hazards. Observations, such as monitoring animal species in the vicinity of the repository, as well as groundwater conditions and sources, are carried out in similar projects in other countries.

Re letter a: The integral monitoring programme shows how the overriding objectives of monitoring a deep geological repository are achieved. To this end, reliable statements about the conditions and processes in a deep geological repository and in its geological environment are determined in order to assess the effectiveness of the barrier system, to facilitate early detection of changes and to reinforce the safety case. A description of possible synergies and interactions with third-party monitoring programmes and the integral monitoring programme are part of the documentation. According to Article 23 of the NEO, a concept for the monitoring period has to be submitted with the general licence application. In the guideline, this specification is extended to the entire deep geological repository as well as all realisation phases.

Re letter b: The term monitoring is widely used in the context of a deep geological repository. The following monitoring aspects apply to a deep geological repository and to the associated surface facilities and near-surface access structures as minimum requirements:

- Monitoring of the geological environment during construction and operation includes appropriate measurements to assess operational and long-term safety and allow statements to be made about the behaviour of the deep geological repository or its environment. Monitoring of the geological environment during construction and operation also serves to build confidence that the deep geological repository behaves in accordance with its design. It continuously complements the geological and hydrogeological database to assess long-term changes in the deep geological repository.
- Radiological environmental monitoring for the purpose of preservation of evidence is carried out in the vicinity of the deep geological repository. It is used

to preserve evidence in the event that a change in environmental properties occurs or has to be assumed during or after construction. In particular, it has to include monitoring of the radioactivity of spring and groundwater, soils, bodies of water and the atmosphere in the area affected by a deep geological repository. Changes in the flow of spring waters may indicate safety-relevant omissions or deviations in the hydrogeological model, for example.

- After orderly closure of the deep geological repository, monitoring can serve as a control and confidence-building mechanism to confirm that there is no indication that the deep geological repository has any unexpected effects on the surface. The RPO and corresponding ENSI guidelines have also to be taken into account for radiological environmental monitoring. The Federal Government monitors environmental radioactivity independent of any monitoring by the operator of a deep geological repository (Articles 191 to 195 of the RPO). Corresponding activities are coordinated jointly between the FOPH and ENSI. ENSI monitors ionising radiation and radioactivity in the vicinity of nuclear installations.
- Radiological monitoring to ensure radiation protection during the operational phase is carried out pursuant to guidelines ENSI-G12 and ENSI-G13. The source-related dose constraint relevant for environmental monitoring is specified in the operating licence. Radiological monitoring begins prior to initial acceptance of waste in order to preserve evidence.
- Monitoring in the pilot facility or experiments in the test areas are used to monitor the waste processes and safety barriers on site and to obtain data to reinforce the safety case (Articles 65 and 66 of the NEO). The results of this monitoring provide the basis for closure of the deep geological repository.
- Monitoring measurements during construction and operation have to allow the assessment of the construction and operational safety of the underground structures and engineered barriers, including the monitoring of the hydrogeological and geotechnical conditions and system behaviour (interaction between the rock mass and cribbing). If necessary, additional measures have to be taken to ensure safety on the basis of the results. Corresponding measures are already planned for the underground structures to be built as part of the underground geological investigations (UGI). For this purpose, reference is made to the principles and regulations in the relevant SIA standards.

Re letter c: The integral monitoring programme for a deep geological repository has to include at least the monitoring aspects listed in b. To provide an overview of the integral monitoring programme, the relationships and boundaries between the various monitoring aspects should be clearly indicated. If possible, reporting should be topic-specific.

Re letter d: Periodic review for suitability (as part of the disposal programme or periodic reporting or licence applications) and any necessary updates to the integral monitoring programme are carried out in accordance with Article 36 of the NEO.

Re letter e: The obligation to monitor a deep geological repository extends over several decades and ends with release from nuclear energy legislation. After orderly closure of the deep geological repository, additional monitoring for a further limited period of time may be stipulated (Article 39 paragraph 3 of the NEA). Monitoring of a deep geological repository has to be undertaken sufficiently early to allow reliable data to be collected for the purpose of preservation of evidence. The time period for monitoring a parameter is defined individually as part of the integral monitoring programme. This applies in particular to the duration of the baseline measurement prior to the first construction activities on the site of the deep geological repository. The integral monitoring programme shows the parameters for which a baseline measurement is required and the proposed timescale.

Re letter f: The purpose of this provision is to ensure that existing data from the site characterisation process, such as data collected for the site selection process and in connection with the underground geological investigations (Section 7.1), is taken into account in the integral monitoring programme.

Re letter h: Periodic reporting on monitoring is covered in Article 37 and Annex 5 of the NEO.

Re letter i: Documenting the monitoring results, including archiving samples (so-called retained samples), keeps open the possibility of extending investigations, for example, if new analytical methods are developed or if the need for independent measurements is identified. Retained samples should permit subsequent safety-relevant control measurements to be carried out until the official assessment of the safety of a deep geological repository has been completed. The procedure for selecting retained samples and their aim and purpose form part of the integral monitoring programme. The retention obligation ends at the latest when the site is released from nuclear energy legislation.

Re Section 6.2 “Pilot Facility”

Article 66 of the NEO already provides detailed requirements on the design of the pilot facility. To fulfil its purpose, the pilot facility has to be representative of the main facility in terms of its construction and inventory. In contrast to the main facility, the pilot facility has to be equipped with monitoring instruments and designed accordingly. For this purpose, the pilot facility may consist of one or more caverns or one or more emplacement drifts. The performance of the barrier system should be monitored in the pilot facility and its environment. This should allow conclusions to be drawn as to whether the main facility will perform correctly. The pilot facility is used to monitor physical and chemical processes and is a simplified representation of the main facility It also serves to inform the public about the evolution of the main facility during the monitoring period.

The duration of the monitoring phase in Switzerland is specified by DETEC on the basis of updated documents after waste emplacement has been completed (Article 68 of the NEO). The Ordinance on the Decommissioning Fund and the Disposal Fund for Nuclear Installations of 7 December 2017 (SEFV; SR 732.17) assumes that the monitoring phase will last for fifty years for the purpose of calculating disposal costs. Taking into account the duration of construction, emplacement operations, the monitoring phase and closure, the stability of the underground structures should be designed to cover a period of more than one hundred years. The monitoring phase project has to be reviewed and updated every ten years (Article 42 of the NEO). If the monitoring phase is too long, this could endanger long-term safety, for example by keeping cavities open for a prolonged period leading to a possible loss of control over the deep geological repository without achieving any significant added value in terms of the information expected.

Re letter a: In order to monitor the conditions in the pilot facility and detect signs of unfavourable interaction between barriers, the following are examples of the aspects that may be monitored:

- Change in temperature distribution over time
- Water saturation
- Pressure conditions (water, gas, rock mass)
- Geomechanical behaviour of the rock mass and microseismicity
- Chemical parameters of the water in pores and fissures
- Gas formation from the waste packages.

Many of the processes anticipated in the main facility progress far too slowly to be measured during the monitoring phase in the pilot facility. It is therefore to be expected that monitoring will only be able to confirm selected aspects of the safety case. Nevertheless, monitoring can also help in detecting unexpected events.

Re letter b: The requirement supplements the specification concerning spatial and hydraulic separation in Article 66 paragraph 3 letter b of the NEO.

Re letter c: In order to ensure that the monitoring period is as long as possible and to be able to react promptly to any unexpected findings from observation of the pilot facility, loading and monitoring of the pilot facility should take place prior to the start of emplacement in the main facility.

Re letter d: The monitoring equipment could compromise the integrity of the pilot facility barriers and thus endanger its long-term safety. Therefore, when designing the underground structures, consideration has to be given to the fact that it may be necessary to transfer waste from the pilot facility to a newly driven emplacement drift to ensure that the pilot facility is in a long-term safe state.

Re Section 6.3 “Permanent Marking”

The Federal Council stipulates that the repository be permanently marked (Article 40 paragraph 7 of the NEA). IAEA Safety Standard SSR-5 describes permanent marking as a possible measure (in addition to information preservation, documentation and archiving) to reduce the risk of unintentional human intrusion into the repository. According to Article 69 paragraph 3 letter c of the NEO, permanent marking relates to the post-closure phase, in which a deep geological repository is no longer subject to nuclear energy legislation.

Re letter a: The guideline obliges the operator to develop proposals for permanent marking of a deep geological repository. Permanent marking has to be suitable for the specific location and the disposal concept of the repository. The concept to be submitted with the construction licence application has to take into account engineering, scientific, social and cultural aspects and has to be defined further in a level-appropriate manner during subsequent project phases. It should, however, be noted that according to current plans, submission of the construction licence application for the L/ILW or HLW repository is not scheduled until at least 2041 or even 2045.

The options for marking repositories have been studied by various countries for many years. None of these countries, and none of the projects pursued to date, assume a marking period of one million years. This is based on the premise that neither natural nor artificial barriers, remains or sources will prevent intelligent beings from accessing deep geological repositories; this would only be possible by sending clearly recognisable messages to these individuals. The generally accepted period for marking is in the range of several thousand years. This is also supported by assumptions concerning the significant decrease in the radiotoxicity of the waste emplaced over this period. Accidentally accessing a sealed deep geological repository in the distant future cannot be ruled out and has to be taken into account in the safety assessment for the post-closure phase (division of the facility into several separate sub-areas, avoiding foreseeable conflicts between resources, etc.).

In principle, it is accepted that warnings against accidental human intrusion by future societies make sense and should be provided. Options and methods for achieving this aim were discussed as part of a project organised by the OECD Nuclear Energy Agency (NEA) on the Preservation of Records, Knowledge and Memory (RK&M) across generations, which took place from 2011 to 2018. One of the project’s findings was that permanent marking of a deep geological repository is only one instrument amongst many for ensuring the transfer of information and knowledge to future generations after closure of the deep geological repository, which is legally enshrined in the NEO. Permanent marking of a deep geological repository can help prevent people from accidentally accessing a closed deep geological repository.

However, deliberate intrusion of humans in a deep geological repository or targeted damage to a deep geological repository need not be taken into consideration in the safety assessment for the post-closure phase (see Section 9.3.4). Accordingly, deliberate intrusion need not be included in the permanent marking concept. To date, the IAEA has yet to formulate any recommendations on how marking should be carried out. From ENSI’s point of view, the legal

requirement for permanent marking is met if the marking remains for several millennia after closure of the deep geological repository.

Re letter b: Long-term safety has the highest priority; this must not be compromised by the marking. For example, safety marking would pose problems if it were still recognisable in the distant future, but could no longer be interpreted correctly. It could arouse curiosity and increase the risk of intrusion in the repository still further.

Re Section 7 “Activities for Deep Geological Disposal”

Re Section 7.1 “Geological Investigations”

Re letters a and b: Pursuant to Article 35 of the NEA, geological investigations are used to obtain information in respect of a deep geological repository and require a licence from the responsible department. Geological investigations may adversely affect the suitability of the site by compromising the geological barriers.

Exploratory boreholes (deep and quaternary boreholes) are bored from the surface and penetrate the effective rock containment zone partially in a destructive manner. ENSI compiles expert opinions for all exploratory boreholes requested with reference to Article 35 of the NEA. In particular, checks are carried out to assess whether the damage to the underground area is limited to the minimum required in order to acquire the relevant information. With regard to the scope and objectives of these exploratory boreholes, ENSI refers to its detailed definitions of the safety specifications for stage 3 of the Sectoral Plan for Deep Geological Repositories and the sources cited therein (ENSI 33/649). Various surveys, such as seismic or geoelectrical measurements and collection of spring and groundwater samples, are also used to characterise the underground area, but do not penetrate the effective rock containment zone in a destructive manner. Therefore, they are not covered in this guideline. However, they may be subject to cantonal or other federal licensing obligations (see Article 61 of the NEO).

Underground geological investigations (UGI) are conducted from underground structures and begin with opening up the underground area using shafts, ramps and exploratory tunnels. UGI are planned after the general licence is granted and come to an end once the nuclear construction licence is granted. UGI may subsequently be incorporated in the underground test areas specified in Article 65 of the NEO or other parts of the deep geological repository provided that the corresponding suitability requirements have been demonstrated and confirmed.

Re letter c: Exploratory boreholes or tunnels partially penetrate the effective rock containment zone and may impair its barrier effect. However, impairment of the safety functions of a deep geological repository should be ruled out, which is why a safety distance is required. Any areas that may have been disturbed due to geological investigations and mining of a deep geological repository has to be taken into account when determining the safety distance.

Re Section 7.2 “Emplacement”

Re letter a: The requirements for emplacement operation are defined in the operating regulations for the deep geological repository. This includes the waste acceptance criteria resulting from the safety case.

Re letter b: The waste acceptance criteria are intended, amongst other things, to ensure that the chemical and radiological inventory of the waste packages meet the corresponding boundary conditions of the safety cases for the operational and post-closure phases.

Re letter c: Once the waste has been accepted, it is repackaged (high level waste) or further packaged (low and intermediate level waste) prior to emplacement. These processes are reviewed by ENSI in advance. With regard to the repackaging of fuel elements from the transport and storage casks to the disposal canisters, it has to be ensured, in accordance with ENSI-G05, that the contents can be unloaded at any time.

Re letter d: This requirement states that means for handling and methods for post-treatment of damaged waste packages should be available.

Re letter e: In accordance with Article 29 paragraph 1 letter f of the NEO, the first storage of waste packages of a given type in a deep geological repository requires approval by ENSI. During this approval process, evidence has also to be provided that the defined suitability criteria for the intended repository area are met.

Re letter g: For deep geological repositories, unlike other nuclear installations, construction, operation and decommissioning (closure) are not completely separate operations in terms of the time they are carried out. For example, during the operational phase, emplacement drifts are driven and then backfilled again at the same time as emplacement of radioactive waste. By imposing this requirement, ENSI ensures that this aspect is given special attention in the safety concept.

Re Section 7.3 “Backfilling and Sealing”

Re letter a: The period during which the emplacement drifts for high level waste are kept open should be as short as possible to minimise damage to the host rock and to minimise the risk from drifts left open in the event of a crisis.

Re letter b: Stabilising and keeping cavities open for long periods (for example, by lining or positioning grids and anchors) should only take place in locations and to an extent that has no adverse effects on long-term safety. Otherwise, as required by the guideline, in the case of emplacement drifts for high level waste, provision should be made for backfilling and sealing immediately after the waste has been emplaced. The operational reliability of the seals is proven in the test areas. Amongst other things, sealing is intended to protect against unintentional water ingress. It can also be used, for example, for mechanical stabilisation, spatial separation, to protect the disposal canisters and to immobilise or retard the dispersal of harmful substances.

Re letter c: The sealing concept includes all intended sealing structures in the deep geological repository.

Re letter d: Evidence is provided by means of appropriate experiments in the test areas according to Article 65 paragraph 3 of the NEO.

Re Section 7.4 “Retrieval without Undue Effort”

Re Section 7.4.1 “General Requirements”

Re letter a: The law states that it has to be possible to retrieve radioactive waste without undue effort (Article 37 paragraph 1 b of the NEA and Article 67 paragraph 2 of the NEO). This applies until the repository is closed. The dispatch from the Federal Council on the Nuclear Energy Act[1] (p. 2756) explains that the waste emplaced prior to closure should be retrievable without undue effort, but that it should also be retrievable after closure, albeit with increased technical effort and financial expenditure. All measures necessary to ensure retrievability must not compromise the effectiveness of the passive safety barriers of a deep geological repository and thus its long-term safety (Article 11 paragraph 2 letter c of the NEO). Prior to commissioning a deep geological repository, it has to be ascertained that any removal of the backfilling material for the purpose of retrieval and the method used to retrieve the waste functions correctly (Article 65 paragraph 2 letters b and c of the NEO). With the exception of proof of the operational reliability of the safety-relevant technologies prior to the start of emplacement and the concepts to be submitted (see Section 7.4.2), no further requirements are stipulated concerning how retrieval will take place in practice, since retrieval without undue effort is not a planned part of operation.

Nevertheless, the safety requirements that apply to retrieval have at least to meet the requirements defined in the operating licence.

Any retrieval of radioactive waste will be facilitated if the disposal canisters remain mechanically intact and thus transportable until the end of the monitoring period (Article 68 of the NEO).

As part of the design, the durability of the underground supporting structures used for any retrieval operations has to be ensured until closure of the deep geological repository. The supporting structure comprises all components and the rock mass that are necessary to ensure equilibrium and maintain the form of the underground structure. The useful life of the underground structures is defined by the waste producers responsible for disposal. The regulations and requirements from the relevant SIA standards (including SIA 197) have to be taken into account where applicable.

[1] 01.022: Dispatch concerning federal popular initiatives "MoratoriumPlus – For the extension of the nuclear power plant construction embargo and the limitation of nuclear risk (MoratoriumPlus)" and "Electricity without Nuclear – For an energy transition and the gradual decommissioning of nuclear power plants (Strom ohne Atom)" and on a Nuclear Energy Act of 28 February 2001.

Re letter b: While the retrieval of radioactive waste could in principle occur not only on the basis of safety considerations, but also on the basis of an evolving state of the art of science and technology, socio-political or economic arguments, the guideline deliberately only defines requirements for the retrieval of waste in the event that the safety case cannot (or can no longer) be made. This could occur, for example, due to the consequences of an accident during the operational phase or due to an unexpected failure of the barrier system during the monitoring period. The possibility that a safety case might also be revised based on operational measures (e.g. by transferring waste within the repository) should also be taken into account (see Section 6.2 d).

Re Section 7.4.2 “Concept for the Possible Retrieval of Radioactive Waste”

The retrieval concept is adapted to the state-of-the-art of science and technology and to the results of monitoring, when submitting the respective applications for the general, construction and operating licences as well as periodically throughout the monitoring period. Previously the retrieval concept only needed to be submitted with the construction licence application. However, assessment reports on Nagra’s waste management programmes have shown that it is wise from a safety point of view to assess the aspects of monitoring, retrieval and closure together and to request a concept for this purpose as early as the general licence application stage.

Re letter a: The concept for the possible retrieval of radioactive waste without undue effort, which has to be submitted with the general licence application, describes the fundamental features of the procedure. These fundamental features also include conceptual considerations regarding the possibility of partial closure of the facility and regarding the minimisation of long-term damage occurring in the underground area.

Re letter b: The concept for the possible retrieval of radioactive waste to be updated with the construction licence application requires an increased level of detail in relation to the corresponding technology and organisation. In this update, retrieval should be distinguished from other processes in which waste is moved again after emplacement. The aim is to show which measures (e.g. for monitoring) are planned so that a retrieval decision can be made on the basis of substantiated knowledge. Retrieval should be considered differently for the various operational phases, for different retrieval scenarios and different conditions of emplacement drifts and disposal canisters (e.g. re-driving backfilled drifts, breaking open sealing sections, removing backfill from the emplacement caverns, picking up and securing disposal canisters and their backhaul to the surface). Measures to ensure that retrieval is possible until repository closure should be presented along with their impact on long-term safety. The radiation exposure for personnel and the general public resulting from a retrieval operation should be estimated and compared with the consequences of non-retrieval.

The project to be submitted with the construction licence application to demonstrate operational feasibility indicates the demonstration tests and waste packages to be used to demonstrate the retrieval technology and its operational reliability under the conditions to be expected

at a later stage, and explains why these selected waste packages are representative of or cover all other waste packages. Any required retrieval of radioactive waste from repository caverns or drifts would take place under conditions that can only be reproduced to a very limited extent above ground (constricted conditions, elevated temperatures, radiation).

Re letter c: When the retrieval concept is updated, it should take into account not only experience resulting from the demonstration of operational feasibility according to Article 65 paragraph 2 letters b and c of the NEO, but also the currently planned monitoring systems, which provide an important basis for the decision on possible retrieval.

Re letter d: A valid and demonstrably functioning retrieval concept should always be available throughout the operational phase. The corresponding techniques have to be tested, but the corresponding devices and materials do not need to be available.

Re letter e: Fundamental changes in the concept might arise, for example, if the seals and backfilling elements were adapted during the operational phase in such a way that the devices and materials previously intended for retrieval can no longer be used and the results of the original demonstration experiments are no longer valid.

Re Section 7.5 “Temporary Closure during the Operational Phase”

Re letter a: Measures required for temporary closure are intended to ensure that, in the event of an unfavourable development in the general conditions that calls into question the safety of the repository or orderly closure, the emplacement areas can be transferred to a passive safe state for a period lasting from several decades to several centuries. Temporary closure differs from orderly closure (Article 39 paragraphs 3 and 4 of the NEA) due to the faster response and the fact that the measures taken can be reversed. Reasons for temporary closure may be, for example looming societal instability, an imminent state of war, epidemics or an economic collapse.

The implementation of a temporary closure is expected to take a few weeks to a few months, corresponding to a simplified (partial) sealing of the facility. The exact requirements have to be assessed on a project and situation-related basis. It is possible that a temporary closure will have to be reversed or replaced subsequently in order to resume work in the deep geological repository or to carry out safe final backfilling and sealing of a deep geological repository in accordance with the requirements for long-term safety.

Re letter b: Measures required for the implementation of a temporary closure should be considered as early as during the repository design phase. In particular, care should be taken to ensure a sufficient distance between the repository areas that are not backfilled during the temporary closure and waste that is already emplaced, so that the necessary barrier effect of the host rock in the vicinity of the waste canisters is not impaired by a rock fall or collapse of the open repository areas. In addition, further measures, such as the continuous backfilling of the emplacement drifts (Section 7.3 a), should support the objective of the temporary closure.

Re c: Precautions relate to planned measures required for the implementation of the temporary closure in the underground facilities.

Re letter d: The aspects mentioned (implementation measures, materials, time requirements) may have design-defining consequences and may thus be important for the construction licence application.

Re Section 7.6 “Closure of a Deep Geological Repository”

A deep geological repository has to be designed in such a way that it can be closed within a few years (Article 11 of the NEO). According to Article 69 of the NEO and Article 39 of the NEA, closure means transferring a deep geological repository to a state in which no further measures are required to ensure long-term safety. Closure includes backfilling all parts of the deep geological repository that are still open after the monitoring period, transferring the pilot facility to a long-term safe state and sealing those parts of the facility that are critical with regard to long-term safety and security. A closure concept has to be submitted with the general licence application in accordance with Article 13 of the NEA. The aspects listed in accordance with Article 69 of the NEO are documented in a level-appropriate manner in the required concept and in the plan (construction licence application) or project (end of emplacement operation) to be submitted at a later date.

Re letter a: In accordance with Article 24 paragraph 2 letter f of the NEO, plans for decommissioning and closure has to be submitted with the construction licence application and updated during operation in accordance with Article 42 of the NEO. Letter a meets WENRA’s recommendation DI-59, which states that the plans should also be updated for the operating licence. A decommissioning plan should be submitted for all parts of the repository that are to be completely removed after the emplacement phase, in particular the surface facilities and near-surface access structures. The project for the monitoring period and the closure plan (Article 42 of the NEO) are particularly relevant for the underground structures.

Re letter b: The closure plan has to be submitted with the construction licence application in accordance with Article 16 of the NEA. This should mention the impact of closure on construction of the entire repository.

Re letter c: The requirements for the sealing structures are first set out in the closure plan for the construction licence in accordance with Section 7.6 letter b. These may change in the course of planning and design on the basis of new findings. Evidence that these requirements are met is based on the findings obtained from testing the sealing in accordance with Article 65 paragraph 3 of the NEO.

Re letter d: Pursuant to Articles 50 and 63 of the NEA, the waste producers responsible for disposal have to submit an application prior to closure. The application for closure after the monitoring period specifically requires an updated safety assessment as evidence of the passive safe state after closure.

Re letter e: The findings from the closure operations have to be included in this safety case for the post-closure phase. This forms the basis for the final safety case according to Article 71 paragraph 2 letter d of the NEO and the order for release of a deep geological repository from nuclear energy legislation.

Re Section 8 “Civil Engineering Design and Construction”

Re Section 8.1 “Underground Structures”

Re Section 8.1.1 “Basic Requirements”

Re letters a and b: The construction licence will be granted if, amongst other things, professional project implementation is guaranteed and a programme of measures for quality assurance of all construction activities is available (Article 16 paragraph 1 letter d of the NEA). Reference is made to the relevant standards that apply at the time of planning. The procedure for handling deviations from the standard, for example as a result of new developments and findings, is regulated in the SIA standards (e.g. SIA 197).

Re Section 8.1.2 “Design”

Re letter a: In the service criteria agreement (see standards SIA 197 and SIA 260), the waste producers responsible for disposal define and justify the service requirements specific to the deep geological repository from construction, operation, structural maintenance, retrievability of the waste, repository closure and long-term safety in a repository type-specific manner.

The planning phases of a construction project are described in standard SIA 197 and are assigned to the approval steps defined in the NEA by the waste producers responsible for disposal. The corresponding design phases (as part of a planning phase) are defined by the waste producers responsible for disposal based on standards SIA 112 and SIA 197. The partial targets pursued and services arising in the individual phases and sub-phases of the planning process according to the SIA standards (see SIA 197, Appendix B) are defined for a deep geological repository by the waste producers responsible for disposal on the basis of their project-specific requirements.

Re letter b: An appropriate level of detail of the repository projects is required so that, amongst other things, geotechnical hazard scenarios can be assessed by means of a risk analysis, rock mechanical and, geotechnical analyses can be carried out, static calculations can be performed, and safety requirements can be assessed. The level of design detail will be enhanced in the future planning phases until execution. The waste producers responsible for disposal will provide justification if individual underground structures are not considered in the respective planning phase. Depending on the relevance of individual underground structures for safety, the selected level of detail may be further enhanced in the respective planning phase.

Re letter c: The repository projects are developed taking into account site-specific hydrogeological and geotechnical data and the resulting interpretations and assessments of the expected hydrogeological and geotechnical conditions. Reliable statements are also valid considering the existing variabilities and uncertainties in data and processes. Site-specific and depth-dependent rock mass properties, geotechnical parameters and their variabilities and uncertainties are covered and their effects on design are shown. Appropriate constitutive models are developed and validated for the host rock on the basis of reliable site-specific data so that the hydromechanical rock mass behaviour and system behaviour (interaction between rock mass and lining) can be adequately assessed.

Site-specific underground models with longitudinal profiles and data bands form part of the basic information. They will be updated in subsequent planning phases as new data will be obtained and existing information will be updated. Possible hazards arising from the ground and the rock mass (e.g. rock collapses or water ingress) and their probable combinations (hazard scenarios) during construction and operation are analysed and evaluated in accordance with the relevant SIA standards. Appropriate measures are taken to control the relevant hazards and hazard scenarios or to limit them to an acceptably small level. The planned safety measures are reviewed when new findings become available. Their effectiveness and the remaining accepted risks (residual risks) are also shown. Reference is made to standard SIA 199, Appendix E, in respect of hazards and hazard scenarios (see Section 5.2.2 letter g).

Re letter d: The risk analysis is carried out as early as possible during the planning phase in accordance with current practice in the construction industry and the relevant standards and is updated in subsequent planning phases (see ENSI 33/649, Section 4.3.2). Events refers to hazards and hazard scenarios. The estimated risks are used to check possible variants and arrangements of the access structures and the essential underground structures at repository level in subsequent planning phases until their final design. The civil engineering risk analysis takes into account the entire underground repository structure (including access structures and portal areas), unless otherwise justified. Variants, for example, for access configurations, are included in the analysis. In justified cases, individual underground structures need not to be considered in the risk analysis.

If the measures defined in the project do not meet the requirements for the structures (referred to as protection objectives in the SIA standards, e.g. SIA 197) as defined in the service criteria agreement, additional measures have to be planned.

Re letter e: The lining of the emplacement drifts and caverns should be planned taking into account its interaction with other barriers, such as backfilling or the host rock, and the processes occurring over the short to long term (e.g. pH plume). Possible changes in rock and rock mass conditions at the repository level as a result of changes in temperature should be considered.

Re Section 8.1.3 “Construction”

Re letter a: The selected excavation methods and the planned excavation support should provide sufficient flexibility to cover variations in the ground or groundwater conditions.

Excavation and construction works to build the underground structures are planned, carried out and monitored to meet the requirements of construction, operation and long-term safety. This is particularly important in the case of HLW emplacement drifts, if this work is carried out at the same time as the emplacement of the waste in HLW emplacement drifts that have already been constructed.

Re letter c: Construction documents are created separately for each underground structure and are updated according to the planning phase. These include, amongst other things, the documents listed in Standard SIA 197.

Construction documents form an important basis for ENSI’s regulatory activities during the monitoring period. They are subdivided and presented in such a way that they contain a clear overview of all the essential information about the building facilities and operational equipment (including monitoring equipment).

Re Section 8.2 “Surface Facility and Auxiliary Access Facilities”

This sub-section addresses specific concerns relating to the safety-relevant structures of the surface facility and auxiliary access facilities.

Re letter a: The procedure for constructing the surface facility and auxiliary access facilities has to take into account the four hierarchy levels B1 to B4 described in Annex 4 of the NEO. In addition to the design basis specified for hierarchy level B1 in Annex 4 of the NEO, according to guideline ENSI-A04 a quality assurance concept has also to be submitted at hierarchy level B1.

Re letter b: The safety assessments defined in Section 9.2 of guideline ENSI-G03 provide, amongst other things, information about the ground properties, groundwater conditions and the hazards to be taken into account. The data required for structural modelling and specification of actions has to be derived from the safety assessments, in order to avoid contradictions between the safety assessment and the building design. The building classification is also based on the findings of the safety assessments.

Re letter c: The design rules according to the SIA standards with regard to specification of loads and load combinations, dimensioning rules, structural design, parameters of building materials, quality requirements, etc. shall apply as a general rule. Alternative standards may be used, if a specific subject is not covered in the SIA standards and the alternative standard is comparable, in terms of its methods, with the SIA standards (partial safety factor principle).

Re letter d: Actions resulting from natural events such as earthquakes, wind, tornadoes or heavy rain have to be derived from the safety assessments and are not taken from the SIA standards. Accidental design situations are defined in SIA 260, paragraph 4.4.3.5; permanent

and temporary design situations in SIA 260, paragraph 4.4.3.4. The accidental actions resulting from natural events with a frequency of 10^{-4} per year may not be lower than the corresponding actions according to the SIA standard, which according to SIA 260 have to be increased with load factors for permanent and temporary design situations.

Re letter e: To avoid permanent damage to buildings, the supporting structure should be designed to ensure linear elastic structural behaviour, even with natural events occurring with a frequency of 10^{-4} per year. For the case of an aircraft impact, limited building damage is permitted, but aircraft parts and kerosene must not penetrate into safety-relevant parts of buildings. Concrete spalling on inside walls has to be limited in such a way that equipment and stored goods are not endangered. The permissible steel strain rates for aircraft impacts are specified in IAEA Safety Report SRS-87 (Safety Aspects of Nuclear Power Plants in Human Induced External Events: Assessment of Structures).

Re letter f: For concrete components with a barrier function (a transfer cell, for instance), the number and width of cracks should be limited to safely contain radioactive substances and protect decontamination coatings. High requirements are defined in standard SIA 262, paragraph 4.4.2.2.6. In particular, steel stresses are limited according to SIA 262, Table 16 and Figure 31.

Re Section 9 “Safety Case”

A safety case proves that the applicable safety requirements have been met. It is based on arguments and evidence that describe, quantify and prove the safety of a deep geological repository. It includes safety analyses and additional qualitative safety assessments and provides information on the reliability of the evidence.

Pursuant to Articles 13, 16, 20 and 39 of the NEA for the operational phase (operational safety) and for the post-closure phase (long-term safety) of a deep geological repository, appropriate safety cases have to be submitted along with the licensing applications (general, construction and operating licence) and with the application for closure of a deep geological repository. Each safety case should demonstrate that the protection of humans and the environment is ensured. Human and organisational factors form part of the safety case (see Section 11 re letter d).

The safety report is the central document for demonstrating safety in licensing procedures based on the NEA and thus forms a basis for technical and political discussions and decision-making. It describes the deep geological repository project and evidence of operational and long-term safety. The report summarises how the designer has optimised the design of the deep geological repository and describes the safety relevance of existing uncertainties.

The specifications for the safety report for the general licence application are documented in ENSI 33/649.

Amongst other things, the reasons for the construction design chosen by the designer are set out in the safety report for the construction licence application. The report also lists the reasons which could lead to a deviation from the planned design of the deep geological repository. Experience shows that a certain degree of design flexibility is necessary, for example, so that the geological conditions actually encountered or technological improvements can be taken into account.

The subsequent safety reports for the operating licence and the closure order describe the reasons for any deviation from the design according to the previous licenses and the form that this has taken. The effects of these deviations on long-term safety have to be demonstrated in such cases.

Re Section 9.1 “Basic Requirements”

Re letter b: The required level of detail is discussed in Section 9.2 for the operational phase and in Section 9.3 for the post-closure phase. The data should be up-to-date so that the safety of the respective licensing step or the respective provision pursuant to the NEA can be assessed.

Re letter c: Uncertainties in the data, processes and model concepts as well as in the future evolution of a deep geological repository are inevitable. How uncertainties are handled forms a central element of the safety case and the safety assessment. In order to demonstrate the robustness of the barrier system’s effect, developments that are less likely or even purely hypothetical ("what if" cases) are also considered.

Systematic examination of the influence of uncertainties on long-term safety serves to strengthen confidence in the evidence on long-term safety, to highlight future research needs and to optimise the design of the deep geological repository.

Re letter d: This refers to findings that may have a significant influence on operational or long-term safety (see also Article 41 paragraph 1, Annex 3 and Annex 5 of the NEO). The frequency is defined when the operating license is granted.

Re letter e: After ENSI has examined the safety case and the Federal Council has declared the site closed, the deep geological repository is no longer subject to nuclear energy legislation (Article 39 paragraph 1 of the NEA).

Re Section 9.2 “Safety Case for the Operational Phase”

Re letter a: In addition to the aspects regulated by the guideline, the safety case for the facility includes the following points, which are already covered in the NEO, the RPO or other guidelines:

- A description of the above and below-ground facilities, including spatial conditions, the most important operational equipment, typical workflows and the respective radiological conditions (activity inventories, dose rates and

contamination) during normal operation (see Articles 23 and 24 and Annexes 3 and 4 of the NEO, Article 124 of the RPO)

This description also contains detailed drawings and plans depending on the stage of the licensing procedure, insofar as these are necessary for the safety case (see Annex 4 of the NEO).

- A description of the structures, systems and components (SSCs) and the organisation and processes intended for nuclear safety

  This also includes radiation protection during normal operation and in the event of malfunctions as well as emergency preparedness. The requirements for SSCs can be found in Articles 10 to 12 of the NEO and in guidelines ENSI-G01, ENSI-G02, ENSI-G12 and ENSI-G13. Requirements concerning organisation are derived from Article 30 of the NEO and guideline ENSI-G07. Important processes for maintaining safety are described in Articles 25 and 31 to 42 of the NEO.

- The expected radiation exposure of personnel and the general public during normal operation (see guidelines ENSI-G14 and ENSI-G15)

- Proof that nuclear criticality cannot occur during the entire operational phase, both during normal operation and in the event of an accident (e.g. assumed flooding by water) (see Section 5.1 d)

Re letter b: The safety case for the operational phase is subject to the existing regulations for nuclear installations. The requirements for the safety case for the general licence application are defined in memo ENSI 33/649, Section 5.1.

Re letter c: This specifies that the safety case for the operational phase has to be provided for both underground and surface facilities.

Re letter d: In contrast to the existing nuclear facilities in Switzerland, construction and operation of a deep geological repository may not be completely separate steps in the life cycle of the nuclear facility. During the emplacement phase, the first stage of the nuclear operation below ground, the waste canisters are emplaced in emplacement drifts or caverns and new emplacement drifts or caverns may be driven concurrently. This may result in special requirements, for example with regard to fire protection, radiation protection or ventilation of underground structures.

Re letter e: Based on the deterministic and probabilistic safety assessments and the resulting potential radiological exposure for the general public during the operational phase, precautions for emergency preparedness inside and outside the facilities have to be identified. Attention has to be paid to the requirements of the Emergency Preparedness Ordinance of 22 October 2010 (NFSV; SR 732.33, in particular Articles 6 and 7), guideline ENSI-B12 and radiation protection legislation (in particular Article 125 of the RPO). Furthermore, clarification should be sought as to whether emergency preparedness zones should be established according to

Article 3 of the NFSV or whether a different regulation is possible due to the low risk based on Article 4 of the NFSV.

Re letter f: In the course of the safety assessments, the effects of accidents during the operational phase on personnel, the public and the environment are considered and protective measures are taken as necessary. However, the effectivity of the barriers can also be reduced by accidents during the operational phase. For this reason, additional measures may be necessary so that long-term safety is still ensured.

Re Section 9.3 “Safety Case for the Post-Closure Phase”

Re letter a: The safety case contains an overall assessment of the long-term safety of a closed deep geological repository. The safety case determines to what extent the deep geological repository components and barriers fulfil the safety functions required of them in the light of the future developments under consideration. The reliability of the data sets, quality assurance measures, methods and the conclusions of the safety assessment are also evaluated. If necessary, additional arguments supporting the data sets and results of the safety assessment, and the conclusions of the safety case may be listed. If possible, the conclusions of the safety assessments have to be supported by natural analogues. Natural analogues are defined as geosystems, materials and processes in nature which are relevant for a deep geological repository and whose past behaviour can be investigated over long periods of time. This includes anthropogenic materials that have been exposed to natural processes for long periods of time. By examining such natural analogues, it is possible to estimate possible developments and assess the long-term safety of a deep geological repository.

The safety case assesses the effectiveness of the multiple barrier system. This can be assessed, amongst other things, on the basis of safety functions such as waste containment, delayed release of radionuclides or retention in the multiple barrier system.

For the post-closure phase, the safety case is managed in a level-appropriate manner. The assumed development of a deep geological repository is based on local and regional geological conditions and on existing findings from ongoing investigations and monitoring programmes.

Re letter b: The uncertainties to be identified and quantified in the safety report include uncertainties regarding conceptualisations, computer models, scenarios and parameters. The overall uncertainty of the deep geological repository system can also be reduced by adapting the design of the deep geological repository. The RD&D report produced by the waste producers responsible for disposal, as required by the Federal Council, which is updated at least every five years as part of the disposal programme or, if necessary, on the basis of the findings of the safety report, provides information on the necessary research and data collection.

Re letter c: The above effects may, for example, include expansion of the excavation-damaged zone, desaturation of the host rock depending on the life of tunnel structures, and roof collapses during tunnel driving.

Re letter d: Pursuant to Article 22 paragraph 2 letter h of the NEA, experience from comparable facilities has to be taken into account.

Re Section 9.3.1 “Safety Assessment”

Re letter a: The scope and depth of the safety assessments depend on the respective licence application and are level-appropriate.

Re letter a number 1: The description includes, for example, the waste inventory, variation over time of the radiological toxicity of the emplaced waste, allocation of waste, the barrier system and the geological situation. It also includes the description of the safety concept and safety functions.

Re letter a number 3: Calculations, experiments and observations can be used for this purpose.

Re letter a number 4: The near field is influenced by thermal, hydraulic, mechanical and chemical interactions, so-called coupled THMC processes. These include, for example, temperature changes around the HLW repository, re-saturation, two-phase flow, mechanical deformation of the host rock and propagation of a pH plume in the host rock.

Re letter a number 5: The description of the long-term geological evolution includes, for example, seismicity, neotectonics and glacial degradation.

Re letter a number 6: The expected development of the materials, waste and engineered barriers in the deep geological repository includes, for example, corrosion of the disposal canisters and dissolution of vitrified waste.

Re letter a number 7: The range of variation of possible releases of radioactive substances into the biosphere and the maximum doses for all scenarios should be determined by defining calculation cases. These provide information on the behaviour and robustness of the overall system.

Re letter a number 8: Simplified assumptions when conceptualising and using the computer models are permissible if it is possible to show what these simplifications mean and how they affect the results. Validation on the basis of experimental data increases confidence that the computer models and input values used adequately describe the processes under consideration.

Re letter a number 9: Sensitivity and uncertainty analyses provide valuable information on any further investigations and method developments that may be necessary to reduce the existing uncertainties associated with the input values and models. They can show whether the calculation results are dependent on possible simplifications. Probabilistic calculations can be used to quantify the risks associated with the scenarios, taking into account the parameter ranges and associated uncertainties. If probabilistic calculations are used, unrealistic parameter combinations should be avoided. In addition, risk dilution in line with Paragraph 5.68 of IAEA Safety

Standard SSG-23 should be avoided. At the same time, evidence should be provided that the risk contribution of rare cases with large radiological effects has been taken into account.

Re letter a number 10: The biosphere may be subject to major changes over long periods of time. Therefore, steps have to be taken to ensure that envelope scenarios cover the effects of a deep geological repository. In the evolution of area morphology, for example, glacial gully formation and erosion should be taken into account.

Re letter c: Potential changes in a deep geological repository are determined by the properties of its components and the sequence of features, events and processes (FEPs) that influence the release of radionuclides from the repository and their transfer into the human habitat (the biosphere). The FEPs are initially derived from an understanding of the system under consideration, but are usually checked by comparing with international FEP databases from previous repository projects. The scenarios within which the disposal system is expected to develop are defined based on the relevant FEPs. Simplifications to allow similar scenarios to be grouped together are permitted to prevent the scenarios being classified in too much detail. Calculation of the radiological consequences of envelope variants for the evolution of a deep geological repository assumes that the actual evolution will not be associated with a greater release than is shown in these evolution variants. If need be, conservative assumptions for the choice of model approaches and model parameters may also be included in the calculations. These include scenarios in which the repository is uncovered and accidental human intrusion. Conventionalised assumptions such as biosphere modelling can also be used when modelling scenarios.[2]

Re Section 9.3.2 “Time Period for Assessment”

Re letter a: The required assessment period of up to one million years is derived from the change over time of the radiological hazard potential of the emplaced spent fuel elements and from the periods of time (up to several million years) for which reliable evidence on long-term geological evolution in Switzerland is possible. Pursuant to Article 4 of the NEA, humans and the environment have to be protected against ionising radiation. Evaluation of the potential radiological effects of a deep geological repository has to take account of the inevitable uncertainties that increase with the time span. For example, engineered barriers, host rocks, surrounding geological formations, biosphere and human lifestyles each have different predictabilities over time.

If it can be shown that, due to the radiological hazard potential of the waste, the deep geological repository can be expected to have only negligible radiological effects on humans and the environment after less than one million years, the assessment period can be shorter.

[2] See IAEA Safety Standard SSG-23, NEA No. 6923 and Vigfusson, J., Maudoux, J., Raimbault, Ph., Röhlig, K.-J., Smith, R. E.: European Pilot Study on The Regulatory Review of the Safety Case for Geological Disposal of Radioactive Waste – Case Study: Uncertainties and their Management

Re letter b: If the maximum radiological effects occur after the end of the assessment period, the calculated radiation exposure of a definable population group should be regarded as an indicator to assess the potential radionuclide release into the biosphere.

Re letter c: The criterion described in Section 4.3.2 letter c is used at the end of the assessment period.

Re Section 9.3.3 “Assumptions regarding Climate Change and Human Lifestyles”

Re letter a: The protection of the environment against radioactive substances from the deep geological repository should also be conservatively assessed for scenarios without any settlements (e.g. during a glacial period) on the basis of the same criteria as for scenarios in which settlements are possible (see the guiding principle for protection of the environment, 4.2d).

Re letter b: Amongst other things, the dose calculation is based on assumptions about radiation sensitivity and human lifestyles in the distant future. The guideline requires that the assumptions made are credible from today’s perspective. This means that, based on the presumed local and climatic conditions, the possibility of a settlement and human lifestyle (including self-sufficiency) similar to present-day humans should be assumed. The results of the individual dose calculation are used to evaluate the release of radioactive substances from the deep geological repository and thus to evaluate the future protection function of the deep geological repository. Scenarios analysing the consequences of human actions have also to be included when evaluating long-term safety. The assumptions for future human actions should be based on the activities of present-day society (for example, in the construction of reservoirs, tunnel or well structures, and exploratory drilling).

Re Section 9.3.4 “Developments not to Be Considered”

Re letter a: Intentional intrusion into the deep geological repository is understood to mean actions carried out with full knowledge of the hazard posed by the emplaced waste. Those carrying out the actions are therefore responsible for any consequences that may arise.

Re letter b: Intentional damage is taken to mean terrorist acts or acts of war, for example.

Re letter c: These are extremely rare processes such as meteorite impacts. One example of this is when a meteorite struck the Nördlinger Ries about 15 million years ago, as a result of which an entire region was destroyed, leading to a deep crater.

Re Section 10 “Security and Safeguards”

Re Section 10.1 “Security”

Re letter a: Personnel security measures, in particular security guards, are governed by the Ordinance on Security Guards in Nuclear Installations of 9 June 2006 (VBWK; SR 732.143.2). On the basis of this ordinance and the Ordinance on Qualifications required by Personnel in

Nuclear Installations (NPQO; SR 732.143.1), periodic personal security checks should be carried out in accordance with the Ordinance on Personnel Security Checks in Nuclear Installations of 9 June 2006 (PSPVK; SR 732.143.3).

Re letter d: Documents should be classified according to guideline ENSI-G09 if they contain information, which, if it became known, could compromise the safety of the general public.

Re Section 10.2 “Safeguards”

Re letter a: According to Article 4 of the Safeguards Ordinance of 21 March 2012 (SR 732.12), responsibility for supervising safeguards measures lies with the SFOE. This includes national nuclear material controls and accounting, as well as other regulatory activities and tasks arising from Switzerland’s bilateral and multilateral obligations in relation to non-proliferation of nuclear weapons, export controls on nuclear goods and the nuclear fuel cycle. The deep geological disposal of fissile materials places special demands on controls. Amongst other things, the proposals of IAEA Technical Report NF-T-3.1 concerning the control of encapsulation plants and deep geological repositories should be taken into account.

Re letter b: For example, seismic measurements are proposed to detect unreported underground activities in the deep geological repository area and to monitor the surface using satellites and aircraft.

Re Section 11 “Quality Assurance and Documentation”

Re letter a: The required quality assurance takes into account the fact that long-term safety and its demonstration depend on the correct execution of a large number of activities that have to be carried out with a specified quality at each stage of realisation of a deep geological repository. The quality assurance measures for all safety-relevant activities are described in detail in the programmes to be submitted in accordance with Articles 16 and 20 of the NEA and Articles 25 and 31 of the NEO prior to the individual realisation phases of a deep geological repository, taking into account human and organisational factors. The realisation phases include planning, geological investigations, construction, operation, monitoring and closure.

Re letters d and e: Systematic and comprehensive documentation of the requirements for the deep geological repository (requirements management) is important for the long-term preservation of knowledge because the deep geological repository is a cross-generational project. Decisions are linked to the relevant reasons and documented to ensure traceability into the future. This will ensure that all necessary information and the reasons for decisions remain available in the future. This documentation is already important when selecting sites for deep geological repositories. It also includes requirements regarding human and organisational factors.

Re letter f: Even information generated in the planning phase, before the start of construction work for underground geological investigations (UGI, see Section 7.1), may be worth archiving for use in the long term. For example, a subsequent reassessment of facts can be carried out

if the reasons that led to the choice of a particular option are documented in a traceable manner (see Section 11 i). For this reason, an initial documentation concept is required even for the UGI application, and this may include the status of current research projects. Documentation concerns all phases of a deep geological repository as set out in Appendix 2 of the guideline.

Re letter g: Construction and operation documentation for nuclear installations is extensively regulated in the NEA, NEO and in ENSI guidelines and is tried and tested based on current practice. This documentation also covers, in a broader sense, periodic reporting during operation according to Article 22 paragraph 2 letter f and Article 37 paragraph 1 of the NEO and guideline ENSI-B02, and ageing management according to Article 35 of the NEO and guideline ENSI-B01. The civil engineering structure for deep geological repositories has two special features: large parts of these structures lie at depths of several hundred metres below ground, which is why the practice described in Standard SIA 2.3.2 (see Section 2.3.2 of the 2004 version) has to be observed. In addition, the underground structure must not only permit safe operation, but also represents an important element for long-term safety in the post-closure phase.

Re letter h: This provision implements Requirement 22 of IAEA Safety Standard SSR-5, which states that plans have to be drawn up to ensure that knowledge is preserved in the post-closure phase. For archiving after orderly closure, the documentation has to be as durable as possible (e.g. IAEA-TECDOC-1097). Similar to the marking of the deep geological repository, two key points have to be observed: durability of the information media and how long the information remains comprehensible. After closure of the deep geological repository or after an additional stipulated period of monitoring has expired, the documentation is handed over to the competent department, which then assumes responsibility for archiving the information media correctly. Finally, the Federal Council ensures that the information about the repository, the emplaced waste and the protection zone is preserved and that knowledge of this information is retained (Article 40 paragraph 6 of the NEA). By drawing up several copies of the documentation, the Federal Government seeks to permit long-term archiving and storage in different locations in order to prevent loss caused by destructive events.

The life of the information media is not just concerned with the long-term durability of the medium (e.g. paper, film, digital data media), but also the expected lifetime of the technology for reading the information media. Data media that can be read and copied with relatively simple means are preferred. Maintenance measures to be documented include preserving and restoring the target condition and determining and assessing the actual condition of equipment and systems. Maintenance covers servicing, repair and inspection.

Re letter i: Retaining understandable and generally accessible information about a deep geological repository should help reduce the likelihood of accidental human intrusion. However, this does not need to be an essential safety element for the long-term safety of a deep geological repository because it is virtually impossible to guarantee that information transmission will function effectively over very long periods of time. Documentation prepared, archived and managed using long-term durability measures in accordance with these requirements can be

regarded as an extension to the marking concept (see Section 6.3). In addition to information required pursuant to the NEO, additional information may also be deemed necessary for the documentation. For example, the description of the closed facility and site location (letter i number 1) includes a traceable timeline of the planning, construction and operational developments, the geometry and properties of the surrounding geological formations as well as the measures used for marking. In the case of L/ILW, this is essentially the conditioning documentation according to Section 4.3, guideline ENSI-B05. In the case of HLW in particular, information from interim storage in accordance with guideline ENSI-B17 may become relevant, such as the duration of interim storage or the results of monitoring activities.

Appendix 1: IAEA Safety Requirements

ID	No.	Requirement	Included in the Swiss Regulations
SSR-5	2.15 (a)	The dose limit for members of the public for doses from all planned exposure situations is an effective dose of 1 mSv in a year. ...	Article 22 RPO Section 4.3.2 ENSI-G03
SSR-5	2.15 (b)	To comply with this dose limit, a disposal facility (considered as a single source) is so designed that the calculated dose or risk to the representative person who might be exposed in the future as a result of possible natural processes affecting the disposal facility does not exceed a dose constraint of 0.3 mSv in a year or a risk constraint of the order of 10^{-5} per year.	Section 4.3.2 ENSI-G03
SSR-5	Req. 1	Governmental responsibilities The government is required to establish and maintain an appropriate governmental, legal and regulatory framework for safety within which responsibilities shall be clearly allocated for disposal facilities for radioactive waste to be sited, designed, constructed, operated and closed. This shall include: confirmation at a national level of the need for disposal facilities of different types; specification of the steps in development and licensing of facilities of different types; and clear allocation of responsibilities, securing of financial and other resources, and provision of independent regulatory functions relating to a planned disposal facility.	Article 5 NEO

SSR-5	Req. 2	Responsibilities of the regulatory body The regulatory body shall establish regulatory requirements for the development of different types of disposal facility for radioactive waste and shall set out the procedures for meeting the requirements for the various stages of the licensing process. It shall also set conditions for the development, operation and closure of each individual disposal facility and shall carry out such activities as are necessary to ensure that the conditions are met.	Article 11 NEO
SSR-5	Req. 3	Responsibilities of the operator The operator of a disposal facility for radioactive waste shall be responsible for its safety. The operator shall carry out safety assessment and develop and maintain a safety case, and shall carry out all the necessary activities for site selection and evaluation, design, construction, operation, closure and, if necessary, surveillance after closure, in accordance with national strategy, in compliance with the regulatory requirements and within the legal and regulatory infrastructure.	Article 22 NEA Article 33 NEO Section 9 ENSI-G03
SSR-5	Req. 4	Importance of safety in the process of development and operation of a disposal facility Throughout the process of development and operation of a disposal facility for radioactive waste, an understanding of the relevance and the implications for safety of the available options for the facility shall be developed by the operator. This is for the purpose of providing an optimized level of safety in the operational stage and after closure.	Section 4.4 ENSI-G03

SSR-5	Req. 5	Passive means for the safety of the disposal facility The operator shall evaluate the site and shall design, construct, operate and close the disposal facility in such a way that safety is ensured by passive means to the fullest extent possible and the need for actions to be taken after closure of the facility is minimized.	Articles 7 and 11 NEO Section 4.2 a and Section 5.2.2 ENSI-G03
SSR-5	Req. 6	Understanding of a disposal facility and confidence in safety The operator of a disposal facility shall develop an adequate understanding of the features of the facility and its host environment and of the factors that influence its safety after closure over suitably long time periods, so that a sufficient level of confidence in safety can be achieved.	Section 9 ENSI-G03
SSR-5	Req. 7	Multiple safety functions The host environment shall be selected, the engineered barriers of the disposal facility shall be designed and the facility shall be operated to ensure that safety is provided by means of multiple safety functions. Containment and isolation of the waste shall be provided by means of a number of physical barriers of the disposal system. The performance of these physical barriers shall be achieved by means of diverse physical and chemical processes together with various operational controls. The capability of the individual barriers and controls together with that of the overall disposal system to perform as assumed in the safety case shall be demonstrated. The overall performance of the disposal system shall not be unduly dependent on a single safety function.	Article 11 NEO Section 5.2.2 ENSI-G03

SSR-5	Req. 8	Containment of radioactive waste The engineered barriers, including the waste form and packaging, shall be designed, and the host environment shall be selected, so as to provide containment of the radionuclides associated with the waste. Containment shall be provided until radioactive decay has significantly reduced the hazard posed by the waste. In addition, in the case of heat generating waste, containment shall be provided while the waste is still producing heat energy in amounts that could adversely affect the performance of the disposal system.	Section 4.4 e and Section 5.2.2 ENSI-G03
SSR-5	Req. 9	Isolation of radioactive waste The disposal facility shall be sited, designed and operated to provide features that are aimed at isolation of the radioactive waste from people and from the accessible biosphere. The features shall aim to provide isolation for several hundreds of years for short lived waste and at least several thousand years for intermediate and high level waste. In so doing, consideration shall be given to both the natural evolution of the disposal system and events causing disturbance of the facility.	Article 31 NEA Section 5.2.2 and Section 9.3 ENSI-G03
SSR-5	Req. 10	Surveillance and control of passive safety features An appropriate level of surveillance and control shall be applied to protect and preserve the passive safety features, to the extent that this is necessary, so that they can fulfil the functions that they are assigned in the safety case for safety after closure.	Article 39 NEA Articles 66 and 68 NEO Section 6.1 ENSI-G03

SSR-5	Req. 11	Step by step development and evaluation of disposal facilities Disposal facilities for radioactive waste shall be developed, operated and closed in a series of steps. Each of these steps shall be supported, as necessary, by iterative evaluations of the site, of the options for design, construction, operation and management, and of the performance and safety of the disposal system.	Article 5 and 62, and Annex 4 NEO Section 4.4, 9 and 9.3, and Appendix 2 ENSI-G03
SSR-5	Req. 12	Preparation, approval and use of the safety case and safety assessment for a disposal facility A safety case and supporting safety assessment shall be prepared and updated by the operator, as necessary, at each step in the development of a disposal facility, in operation and after closure. The safety case and supporting safety assessment shall be submitted to the regulatory body for approval. The safety case and supporting safety assessment shall be sufficiently detailed and comprehensive to provide the necessary technical input for informing the regulatory body and for informing the decisions necessary at each step.	Articles 13, 16, 20, 21 and 39 NEA Articles 23 and 42 NEO Section 9 ENSI-G03
SSR-5	Req. 13	Scope of the safety case and safety assessment The safety case for a disposal facility shall describe all safety relevant aspects of the site, the design of the facility and the managerial control measures and regulatory controls. The safety case and supporting safety assessment shall demonstrate the level of protection of people and the environment provided and shall provide assurance to the regulatory body and other interested parties that safety requirements will be met.	Section 9 ENSI-G03

SSR-5	Req. 14	Documentation of the safety case and safety assessment The safety case and supporting safety assessment for a disposal facility shall be documented to a level of detail and quality sufficient to inform and support the decision to be made at each step and to allow for independent review of the safety case and supporting safety assessment.	Article 22 paragraph 2 i NEA Annex 3 NEO Sections 9 and 11 ENSI-G03
SSR-5	Req. 15	Site characterization for a disposal facility The site for a disposal facility shall be characterized at a level of detail sufficient to support a general understanding of both the characteristics of the site and how the site will evolve over time. This shall include its present condition, its probable natural evolution and possible natural events, and also human plans and actions in the vicinity that may affect the safety of the facility over the period of interest. It shall also include a specific understanding of the impact on safety of features, events and processes associated with the site and the facility.	Article 5 NEO Sections 7.1 and 9.3 ENSI-G03 ENSI 33/649
SSR-5	Req. 16	Design of a disposal facility The disposal facility and its engineered barriers shall be designed to contain the waste with its associated hazard, to be physically and chemically compatible with the host geological formation and/or surface environment, and to provide safety features after closure that complement those features afforded by the host environment. The facility and its engineered barriers shall be designed to provide safety during the operational period.	Article 11 NEO Section 5 ENSI-G03

SSR-5	Req. 17	Construction of a disposal facility The disposal facility shall be constructed in accordance with the design as described in the approved safety case and supporting safety assessment. It shall be constructed in such a way as to preserve the safety functions of the host environment that have been shown by the safety case to be important for safety after closure. Construction activities shall be carried out in such a way as to ensure safety during the operational period.	Sections 5 and 8.1 ENSI-G03
SSR-5	Req. 18	Operation of a disposal facility The disposal facility shall be operated in accordance with the conditions of the licence and the relevant regulatory requirements so as to maintain safety during the operational period and in such a manner as to preserve the safety functions assumed in the safety case that are important to safety after closure.	Articles 19 to 22 NEA Section 4.3.1 and Section 5.1 e ENSI-G03
SSR-5	4:37	Fissile material, when present, has to be managed and has to be emplaced in the disposal facility in a configuration that will remain subcritical. This may be achieved by various means, including the appropriate distribution of fissile material during the conditioning of the waste and the proper design of the waste packages. Assessments have to be undertaken of the possible evolution of the criticality hazard after waste emplacement, including after closure.	Section 5.1 d ENSI-G03
SSR-5	Req. 19	Closure of a disposal facility A disposal facility shall be closed in a way that provides for those safety functions that have been shown by the safety case to be important after closure. Plans for closure, including the transition from active management of the facility, shall be well defined and practicable, so that closure can be carried out safely at an appropriate time.	Articles 13 and 16, Article 22 paragraph 2 k, Articles 39, 50 and 63 NEA Articles 11 and 69 NEO Section 7.6 ENSI-G03

SSR-5	Req. 20	Waste acceptance in a disposal facility Waste packages and unpackaged waste accepted for emplacement in a disposal facility shall conform to criteria that are fully consistent with, and are derived from, the safety case for the disposal facility in operation and after closure.	Section 7.2 a to c ENSI-G03
SSR-5	Req. 21	Monitoring programmes at a disposal facility A programme of monitoring shall be carried out prior to, and during, the construction and operation of a disposal facility and after its closure, if this is part of the safety case. This programme shall be designed to collect and update information necessary for the purposes of protection and safety. Information shall be obtained to confirm the conditions necessary for the safety of workers and members of the public and protection of the environment during the period of operation of the facility. Monitoring shall also be carried out to confirm the absence of any conditions that could affect the safety of the facility after closure.	Section 6.1 ENSI-G03
SSR-5	Req. 22	The period after closure and institutional controls Plans shall be prepared for the period after closure to address institutional control and the arrangements for maintaining the availability of information on the disposal facility. These plans shall be consistent with passive safety features and shall form part of the safety case on which authorization to close the facility is granted.	Article 40 NEA Article 71 NEO Sections 6.3 and 11 ENSI-G03

SSR-5	Req. 23	Consideration of the State system of accounting for, and control of, nuclear material In the design and operation of disposal facilities subject to agreements on accounting for, and control of, nuclear material, consideration shall be given to ensuring that safety is not compromised by the measures required under the system of accounting for, and control of, nuclear material.	Safeguards Ordinance (SR 732.12) Sections 10.1 and 10.2 ENSI-G03 ENSI-G09 BFE-SG02 BFE-SG03
SSR-5	Req. 24	Requirements in respect of nuclear security measures Measures shall be implemented to ensure an integrated approach to safety measures and nuclear security measures in the disposal of radioactive waste.	SR 732.143.1 SR 732.143.2 SR 732.143.3 Sections 10.1 and 10.2 ENSI-G03 ENSI-G09
SSR-5	Req. 25	Management systems Management systems to provide for the assurance of quality shall be applied to all safety related activities, systems and components throughout all the steps of the development and operation of a disposal facility. The level of assurance for each element shall be commensurate with its importance to safety.	Article 25 NEO Section 11 ENSI-G03
SSR-5	Req. 26	Existing disposal facilities The safety of existing disposal facilities shall be assessed periodically until termination of the licence. During this period, the safety shall also be assessed when a safety significant modification is planned or in the event of changes with regard to the conditions of the authorization. In the event that any requirements set down in this Safety Requirements publication are not met, measures shall be put in place to upgrade the safety of the facility, economic and social factors being taken into account.	Article 22 paragraph 2 d NEA Article 42 NEO Section 9.1 d ENSI-G03

Appendix 2: WENRA Safety Reference Levels

No.	Requirement	Included in the Swiss Regulations
DI-1	The licensee shall have the responsibility for ensuring and demonstrating that the facility is safe until termination of the licence, and for demonstrating that the facility will continue to be safe thereafter.	Article 22 and 39 NEA Section 7.6 ENSI-G03
DI-2	The licensee shall make and implement programmes and procedures necessary to maintain safety.	Article 22 NEA Sections 4.4, 8.1 and 11 ENSI-G03
DI-3	The licensee shall continuously improve safety by, in particular, using experience feedback and advances in science and technology.	Article 22 NEA Sections 4.4 and 9 ENSI-G03
DI-4	The licensee shall establish and implement its safety policy taking due account of national and international standards and ensure that matters related to safety are given the highest priority.	Article 5, 22 and 34 NEA Sections 4.4 and 9 ENSI-G03
DI-5	The licensee shall ensure that the resources (including organizational structure, individuals, experience and skills, infrastructure, working environment, information and knowledge, suppliers, materials) for all necessary activities before termination of the licence will be available at the time they are needed.	Article 22 and 30 NEA Section 11 ENSI-G03
DI-6	After closure and until termination of the licence, the licensee shall remain responsible for surveillance of the disposal system in accordance with the safety case and for any remedial action that might be required.	Article 21 and 39 NEA Sections 6 and 7.6 ENSI-G03
DI-7	The licensee shall ensure that all activities, including those carried out by contractors, are performed and controlled according to the licensee's management system.	Article 30 NEO Section 11 ENSI-G03
DI-8	The licensee shall ensure that interfaces between its responsibilities and those of other organizations are clearly defined, agreed and documented.	Article 30 NEO Section 11 ENSI-G03
DI-9	The licensee shall establish an organizational structure to enable its safety policy to be implemented with a clear definition of responsibilities, lines of authority and communication.	Article 22 NEA Articles 30 and 31 NEO

DI-10	The licensee shall establish the capability in terms of staffing, skills, experience and knowledge to build and maintain the competences required to undertake all relevant activities and adapt its organization progressively in accordance with future plans.	Article 31 NEO VAPK
DI-11	The licensee shall define the necessary qualification, experience and skills for all staff involved with activities that may affect safety.	Article 30 NEO VAPK Section 11 ENSI-G03
DI-12	The licensee shall establish training programmes to develop and maintain the professional skills of its staff, and to ensure that personnel are appropriately trained before beginning each activity.	Articles 30 and 31 NEO VAPK
DI-13	Where any activity related to safety is carried out by a contractor, the licensee shall retain within its organization the capability to assess the adequacy of the contractor's resources and skills for ensuring safety and the quality of the deliverables.	Article 30 NEO
DI-14	The licensee shall establish, document, implement, assess and continuously improve its management system to achieve and enhance safety by bringing together in a coherent manner all the requirements for managing the organization by: • Describing and implementing the planned and systematic actions necessary to provide adequate confidence that all these requirements are satisfied; • Ensuring that health, environmental, security, quality and economic requirements are not considered separately from safety requirements, to help preclude their possible negative impact on safety; • Promoting the development of a safety culture, which includes individual and collective commitment to safety and encourages a proactive, questioning and learning attitude at all levels in the organization; • ...	Section 11 ENSI-G03
DI-15	The licensee shall ensure that its management system covers normal operation conditions, anticipated operational occurrences and possible accidents.	Article 30 NEO Sections 9.1 and 11 ENSI-G03

DI-16	The licensee shall ensure that its management system takes into account safety in design, construction, commissioning, operation, decommissioning, closure and after closure. The licensee shall review its management system at regular intervals to ensure continuing suitability and effectiveness.	Article 16 NEA Section 11 ENSI-G03
DI-17	The licensee shall document in its management system at least the following: • Its safety policy; • A description of its management system; • A description of its organizational structure; • A description of the functional responsibilities, accountabilities, levels of authority and interactions of those managing, performing and assessing work; • A description of the licensee's interactions with contractors, including the control of activities carried out by contractors; • A description of the processes and supporting information that explain how work is to be prepared, carried out, recorded, assessed, reviewed, and improved; • A description of the provisions to record and review knowledge, information and data about all aspects related to safety of the disposal facility and system and to preserve the records; • A description of the provisions to ensure appropriate transfer of knowledge to its personnel throughout the different phases until termination of the licence.	ENSI-G07
DI-18	The licensee shall ensure that, for any operational activity relating to safety, all documents required to demonstrate that it will be undertaken safely (e.g.: operational procedures, operating instructions) have been prepared before beginning that activity.	Articles 25 and 31 NEO

DI-19	The licensee shall establish and conduct an experience feedback programme to collect, screen, analyse and document in a systematic way experience important to safety in all phases of facility development until termination of the licence. This programme shall cover issues of importance for both operational and post-closure safety. This information shall be used for preventing events and processes adverse to safety, and for improving the design or manner of construction and operation of the facility as necessary. Experience from other facilities shall also be considered as appropriate.	Article 36 NEO Section 7.7 ENSI-G07
DI-20	The licensee shall ensure that, during design, construction, commissioning, operation, closure and post-closure until termination of the licence, knowledge and records important to safety are available and updated as appropriate for current activities, safety assessment and long term record keeping on: • Characterisation of the site; • Design basis; • Design; • As built construction of the disposal facility; • Inventory and emplacement of the waste; • State of the disposal system after closure; • All documents relating to the safety case.	Article 22 and 38 NEA Articles 37, 41, 42, 54, 71 and 72 and Annex 4 NEO Section 11 ENSI-G03
DI-21	The licensee shall ensure that, at termination of the licence, records on the site and on the as closed state of the disposal facility are available for continuing preservation, in accordance with the national legal and regulatory framework.	Article 38 and 40 NEA Article 71 NEO Section 11 h ENSI-G03
DI-22	The licensee shall design, construct, operate and decommission a disposal facility, ensure closure and, as appropriate, carry out post-closure surveillance so as to fulfil the objective of protecting people and the environment according to applicable radiological protection criteria, including the ALARA principle. A graded approach shall be adopted proportionate to the hazard presented by the waste.	Articles 8 to 10 RPA Articles 3 to 5 RPO Article 5 NEA Sections 4.4 and 5.2.2 ENSI-G03

DI-23	The licensee shall ensure that safety is provided by means of multiple safety functions, including use of multiple barriers and controls. The performance of these barriers shall be achieved by diverse physical and chemical means. The overall performance of the disposal system shall not be unduly dependent on any single safety function according to the defence in depth principle.	Article 5 NEA Articles 10 and 11 NEO Sections 5.2.2 b ENSI-G03
DI-24	The licensee shall ensure that safety will be achieved entirely by passive means, after closure of the facility and after any subsequent period of active institutional control.	Article 11 NEO Section 4.2 a and Section 5.2.2 a and b ENSI-G03
DI-25	Throughout the process of development (e.g. design, construction, commissioning), operation, decommissioning and closure of a disposal facility, the licensee shall aim for an optimized level of safety considering both operational and post-closure phases.	Article 4 RPO Section 4.4 a and d ENSI-G03
DI-26	The licensee shall design, construct, operate, decommission and close the disposal facility in order to establish a disposal system which provides containment and isolation of the waste for a period of time suited to its radiological hazards.	Article 39 NEA Article 11 NEO Section 9.2.2 ENSI-G03
DI-27	The licensee shall ensure that the disposal system provides isolation and containment during normal evolution and shall establish to a high level of confidence that the disposal system can be relied on to provide isolation and containment over the timescales necessary.	Article 39 NEA Article 11 NEO Sections 5.2.2, 9.2 and 9.2.2 ENSI G03
DI-28	The licensee shall ensure that any provisions to facilitate reversal of disposal operations, or retrieval of waste packages disposed of, have no unacceptable effects on post-closure safety.	Article 11. NEO Section 5.1 d ENSI-G03
DI-29	The licensee shall define and implement an appropriate programme (e.g. through R&D, investigations, modelling, testing and monitoring activities) with the purpose of providing an understanding of the evolution of the disposal system adequate for the safety case.	Article 32 NEA Articles 52, 58, 65 and 66 NEO Sections 6.2 and 9.2 ENSI-G03
DI-30	If construction, operation, decommissioning or closure activities take place concurrently, the licensee shall perform the works so that they will not have an unacceptable effect on operational or post-closure safety.	Section 5.2.2 f, Section 7.2 g, Section 8.1 a, Section 8.1.2 a and Section 9.1 d ENSI-G03

DI-31	The licensee shall ensure that any measures necessary for the purpose of accounting for and control of nuclear material shall not unacceptably affect operational and post-closure safety.	Section 10.2 b ENSI-G03
DI-32	The licensee shall prepare and implement a programme for site characterization of the selected site. The programme shall provide the information necessary to support the safety case.	Article 13 g NEA Articles 5 and 59 NEO
DI-33	The licensee shall conduct site characterisation of the selected site: • To establish baseline conditions for the site and the environment; • To support the understanding of the normal evolution; • To identify any events and processes associated with the site that might disturb the normal evolution of the disposal system; • To support the understanding of the effect on safety of any features, events and processes associated with the disposal system.	Article 35 NEA Articles 60, 65 and 66 NEO Section 6.1 b and f, Section 6.2 a and Section 9.2.1 ENSI-G03
DI-34	The licensee shall design the disposal facility to establish a disposal system which provides operational and post-closure safety. The licensee shall take into account the characteristics of the wastes to be disposed of (e.g.: radioactivity, heat and gas generation), the feasibility of the technical options and the characteristics of the selected site.	Article 20 and 37 NEA Articles 7 and 23 NEO Sections 5 and 9 ENSI-G03
DI-35	The licensee shall establish a design basis for the facility taking into account normal operational conditions, anticipated operational occurrences and possible accidents derived from a relevant set of postulated initiating events (PIEs).	Articles 7 and 8 NEO Section 9.1 a and e ENSI-G03
DI-36	The licensee shall design the disposal facility giving due consideration to both normal evolution of the disposal system after closure and scenarios involving events and processes that might disturb the normal evolution of the disposal system.	Sections 9.2 and 9.2.1 ENSI-G03
DI-37	The licensee shall design the disposal facility giving due consideration to disturbances of the disposal system during operation whose consequences may affect post-closure safety.	Section 5.1 d, Section 8.1 a, Section 8.1.1 d, Section 9.1 f and Section 9.2 c ENSI-G03

DI-38	The licensee shall design the disposal facility to fulfil the following safety functions during the operational and post-closure phases: • Control of the exposure of people and the environment; • Containment and isolation of radioactive material; • Control of sub-criticality, if applicable; If burnup credit is adopted for criticality management, the licensee shall confirm compliance with the limiting minimum burnup level with respect to initial enrichment by administrative and operational controls; • Heat or gas removal, if applicable.	Article 16 and 20 NEA Article 11 NEO Section 5.1 a to c, Section 5.2.2 b to d ENSI-G03
DI-39	The licensee shall identify and classify engineered structures, systems and components (SSCs) in accordance with their importance for operational and post-closure safety.	Article 24 and Annex 4 NEO
DI-40	The licensee shall base the design of the facility on applicable standards, appropriately proven techniques and the use of appropriate materials to ensure that the safety requirements will be met, throughout operation and post-closure.	Article 16, 20 and 22 NEA Article 7 NEO
DI-41	The licensee shall have a process for identifying any conflicting design requirements from different regulatory regimes, and seeking to resolve them.	Section 11 e ENSI-G03
DI-42	The licensee shall design the disposal facility so that the engineered components (including barriers) are, to an adequate extent, physically and chemically compatible with each other, with the waste disposed of and with the host environment.	Section 5.2.2 c ENSI-G03
DI-43	The licensee shall make design provisions for maintenance, testing, inspection and monitoring of structures, systems and components (SSCs), addressing also their ageing.	Articles 24 and 35 and Annexes 3 and 4 NEO
DI-44	The licensee shall establish design provisions for monitoring the host environment.	Article 66 NEO Section 6.1 ENSI-G03
DI-45	The licensee shall incorporate passive safety features for operational safety into the design of the disposal facility as far as reasonably practicable.	Article 10 (1) i NEO

DI-46	The licensee shall design the equipment of the disposal facility to take account of radiation protection aspects, ease of maintenance and inspection, and minimization of the probability and consequences of anticipated operational occurrences and, as far as practicable, possible accidents during handling.	Article 27 NEO Section 5.1 a, b and d ENSI-G03
DI-47	Before starting construction, the licensee shall establish a baseline state of the environment both for supporting the monitoring programme and for evaluating the impact of the facility on the environment.	Section 6.1 b and e ENSI-G03
DI-48	Before starting construction, the licensee shall define and document a systematic monitoring programme to be implemented during construction, commissioning, operation, decommissioning and closure, and as appropriate after closure.	Article 68 NEO Section 6.1 ENSI-G03
DI-49	The licensee shall ensure that the monitoring programme contributes to: • Demonstrating adequate protection of people and the environment and demonstrating compliance with the regulatory requirements and licence conditions; • Confirming that the disposal facility and system behaves and evolves as expected in the safety case; • Building confidence in and refining the key assumptions and models made in the safety case; • Enhancing understanding of the environmental conditions and of the functioning of the disposal system; • Acquiring information for supporting decision-making and; • Providing background information for any post-closure surveillance programme.	Article 38 and 39 NEA Article 66 NEO Section 6.1 b, Section 6.2 a, Section 9.2 d ENSI-G03
DI-50	The licensee shall construct the disposal facility in accordance with the design as described in the safety case and by application of appropriately proven techniques.	Article 16 and 18 NEA Articles 7 and 65 NEO Section 9 d, Section 9.2 d ENSI-G03
DI-51	The licensee shall construct the disposal facility in such a way as to preserve the post-closure safety functions of the host environment.	Article 35 (2) a NEA Article 67 NEO Section 5.1 g, Section 8.1 a and Section 8.1.2 a ENSI-G03

DI-52	In order to refine the assumptions of the safety case, the licensee shall gather information during construction to improve the knowledge of: • The intrinsic properties of the host environment • The response of the host environment to the presence of the disposal facility.	Section 6.1 b and f ENSI-G03
DI-53	The licensee shall plan, assess, document and implement any modifications of design, construction procedures and methods using arrangements consistent with the importance to safety of the modification. These arrangements shall ensure that the modifications will not have an unacceptable effect on operational and post-closure safety.	Articles 26, 27 and 40 NEO
DI-54	The licensee shall operate the facility in accordance with the conditions of the licence and the relevant regulatory requirements so as to maintain safety during the operational phase, and so as to establish and preserve the post-closure safety functions claimed in the safety case.	Article 20 NEA Section 5.1 d and Section 5.2.2 a ENSI-G03
DI-55	The licensee shall make and implement arrangements to detect and respond to anticipated operational occurrences and possible accidents. Provisions for doing so shall not unacceptably affect operational or post-closure safety.	Article 8 NEO Section 5.1 d and Section 9.1 f ENSI-G03
DI-56	In order to refine the assumptions of the safety case, the licensee shall continue to gather information during operation to improve the knowledge of: • The intrinsic properties of the host environment; • The response of the host environment to the presence of the disposal facility.	Article 66 NEO Section 6.1, Section 9 d and Section 9.2 d ENSI-G03
DI-57	The licensee shall establish, substantiate, document and implement operational limits and conditions (OLCs) to operate the disposal facility safely, to maintain the waste in a safe state during operation and to ensure compliance with the requirements for post-closure safety.	Annex 3 NEO Section 7.2 a ENSI-G03
DI-58	The licensee shall make adequate arrangements for commissioning and operation of the disposal facility including arrangements for receiving, handling and emplacement of waste before these activities are commenced.	Article 29 NEO Section 7.2 ENSI-G03

DI-59	Before starting the emplacement of any waste, the licensee shall review the plan for decommissioning, closure and post-closure activities.	Section 7.6 a ENSI-G03
DI-60	The licensee shall ensure that any modifications to the disposal facility will not have an unacceptable effect on operational and post-closure safety.	Article 27 and 33, and Annex 3 NEO Section 9 ENSI-G03
DI-61	The licensee shall plan, assess, document and implement any modifications of design, waste acceptance criteria, structures, systems and components (SSCs), operational limits and conditions (OLCs) and operational procedures and methods using arrangements consistent with the importance to safety of the modifications.	Article 65 NEA Articles 27, 33 and 40 and Annex 3 NEO Sections 7.2 and 9 ENSI-G03
DI-62	The licensee shall prepare and implement an on-site emergency plan to respond to possible accidents requiring protection of the personnel and members of the public. This emergency plan shall be proportionate to the consequences of the possible accidents considered and shall provide for: • Regaining control of the disposal facility in an emergency; • Preventing or mitigating the consequences of any such emergency; If an off-site emergency plan is required, the licensee shall provide the technical basis for its development and implementation.	Articles 5, 7, 8 and 30 NEO Article 125 RPO Section 5.1 ENSI-G03 ENSI-B12
DI-63	For the purposes of emergency planning the licensee shall, as appropriate: • Establish and implement the necessary organizational structure for clear allocation of responsibilities and authorities, • Ensure that, based on the on-site emergency plan, appropriate trained and qualified personnel, facilities and equipment needed to control an emergency will be available whenever they might be required, and • Establish arrangements as necessary for coordinating emergency activities and cooperating with external response organizations throughout all phases of an emergency.	Article 20 NEA Annex 3 NEO ENSI-B12

DI-64	The licensee shall submit the on-site emergency plan to the regulatory body. At regular intervals, the licensee shall carry out emergency exercises, some of which shall be witnessed by the regulatory body. Some of these exercises shall, as appropriate, include the participation of external emergency response organizations. The plan shall be subject to review and updating in the light of the experience gained.	ENSI-B11
DI-65	The licensee shall establish and implement programmes for maintenance, periodic testing and inspection, based on written procedures, in order to ensure and confirm that structures, systems and components (SSCs) are able to function in accordance with the requirements for operational and post-closure safety.	Article 22 NEA Article 32 NEO
DI-66	The licensee shall record and assess the results of maintenance, periodic testing and inspection, important to safety. Results derived from these programmes shall be used to review the adequacy of the design, construction and operation of the disposal facility and to identify any implications for post-closure safety.	Article 33 NEO
DI-67	At regular intervals, the licensee shall review and as necessary revise programmes for maintenance, periodic testing and inspection to incorporate the lessons learned from experience.	Article 33 NEO
DI-68	The licensee shall close the disposal facility in such a way as to provide for the safety functions required after closure.	Article 39 NEA Articles 67 and 69 NEO Section 7.6 ENSI-G03

DI-69	Before starting decommissioning and closure, the licensee shall define the corresponding programme so that it takes into account, as appropriate: • The state of the facility, as constructed and operated including information on waste inventory and emplacement; • Dismantling and removal of operational equipment; • Remaining backfilling and sealing; • Decommissioning of auxiliary structures, e.g. parts of the facility on the surface; • Environmental remediation as required; • Programmes for monitoring and surveillance; • Programmes for security and safeguards; • Plans for preserving knowledge and records about the waste disposed of and the disposal system.	Article 13 paragraph 1 c, Article 16 paragraph 1 e, Article 22 paragraph 2 k NEA Articles 42, 45 and 67 NEO Sections 7.3, 7.6, 6.1, 6.3, 10 and 11 ENSI-G03 Section 5.4.9 ENSI-G17
DI-70	The licensee shall perform decommissioning and closure activities in accordance with the national legal and regulatory framework so as to maintain safety during decommissioning and closure, and so as to establish and preserve the post-closure safety functions claimed in the safety case.	Article 13, 22 and 26 NEA Article 69 NEO Section 7.6 ENSI-G03
DI-71	The licensee shall plan, assess, document and implement any modifications in the decommissioning and closure procedures and methods using arrangements consistent with the importance to safety of the modifications.	Article 65 NEA Articles 27 and 40 NEO
DI-72	After closure and until termination of the license, the licensee shall implement a post-closure surveillance programme, if appropriate. In the event that surveillance demonstrates the need for remedial actions, the licensee shall implement such actions in accordance with the licence.	Article 39 NEA Section 7.6.1 e ENSI-G03

DI-73	As a condition for the termination of the licence, the licensee shall: • Demonstrate that the results of any surveillance programme are consistent with the assumptions of the safety case, to the satisfaction of the regulatory body; • Propose any restrictions on land use, suggest and substantiate the way they shall be implemented, or any other measures deemed appropriate for the post-licensing phase.	Article 39 and 40 NEA Articles 66 and 70 NEO Section 6.1 ENSI-G03
DI-74	The licensee shall contribute to the safe management of the waste by establishing preliminary waste acceptance criteria at the earliest opportunity. The licensee shall update such preliminary waste acceptance criteria to reflect the development of the disposal project.	Section 7.2 a ENSI-G03
DI-75	Prior to the start of waste emplacement, the licensee shall specify waste acceptance criteria so as to ensure the conformity of individual waste consignments to the safety case and other aspects of the disposal arrangements. The waste acceptance criteria shall be consistent with the operational and post-closure safety case and shall be reported to the regulatory body, for approval if appropriate.	Article 37 NEA Section 7.2 a to c ENSI-G03
DI-76	The licensee shall ensure that waste acceptance criteria specify limits on important parameters such as radionuclide inventories and activity concentrations in individual waste consignments. Appendix 2 presents further details of the typical content for low and intermediate level waste.	Article 37 NEA Section 7.2 a to c ENSI-G03
DI-77	The licensee shall specify criteria to ensure that waste accepted for disposal is physically and chemically stable over a timescale consistent with the safety case and compatible with other components of the disposal facility.	Article 37 NEA Sections 4.2.1.5 and 4.2.1.6 ENSI-B05 Section 7.2 b and f ENSI-G03
DI-78	The licensee shall report changes to waste acceptance criteria to the regulatory body, for approval if appropriate. The licensee shall substantiate the consistency of any changes with the assumptions made in the safety case.	Section 7.2 c and d ENSI-G03

DI-79	The licensee shall ensure that the waste accepted for disposal conforms to waste acceptance criteria. A conformity assessment shall be performed in accordance with written arrangements which include administrative procedures, inspections and/or tests.	Section 7.2 d ENSI-G03
DI-80	The licensee shall provide a system for tracing the location in the disposal facility of any waste disposed of.	Section 11 i ENSI-G03
DI-81	To provide an adequate level of assurance that waste characteristics conform to the waste acceptance criteria, the licensee shall satisfy itself that the management system of the organization submitting waste for disposal appropriately addresses waste quality issues.	Section 4.4 ENSI-B05
DI-82	The licensee shall establish procedures for dealing with waste that does not conform to waste acceptance criteria, and shall not accept such waste unless acceptability with regard to operational and post-closure safety has been demonstrated on a case by case basis.	Section 7.2 b and d ENSI-G03
DI-83	The licensee shall provide to the regulatory body a safety case substantiating that operational and post-closure safety requirements as specified in the national legal and regulatory framework are met. The licensee shall update the safety case in accordance with regulatory requirements.	Section 9 ENSI-G03
DI-84	The licensee shall provide assurance through the safety case that workers, members of the public and the environment are and will remain adequately protected against the hazards associated with the waste being disposed of.	Sections 4.1 and 9 ENSI-G03
DI-85	The licensee shall include in the safety case a safety assessment that demonstrates conformity with the safety requirements. The licensee shall also present an evaluation of the technical feasibility of the design and the construction, operation, decommissioning, closure and post-closure activities.	Article 11 NEO Section 5 and Section 9 a ENSI-G03
DI-86	The licensee shall include in the safety assessment for the operational and post-closure phases: • An evaluation of the performance and robustness of the disposal facility and system and its components; • An evaluation of the radiological impact.	Section 9.2.1 a (3) and Section 9.2.2 b ENSI-G03

DI-87	The licensee shall describe in the safety case all safety-important aspects of the disposal facility and system including the waste to be disposed of, the design, the construction, operation, closure, decommissioning and post-closure activities. The typical content of a safety case is given in Appendix 3.	Section 9 ENSI-G03
DI-88	The licensee shall in the safety case take due consideration of future human actions including inadvertent human intrusion. Such consideration should focus on reducing the likelihood and potential consequences of inadvertent human intrusion. Any measures taken to prevent inadvertent human intrusion must not compromise the operational safety of the disposal facility and the post-closure safety of the disposal system.	Article 40 NEA Article 70 NEO Section 6.3 and Section 9.2.4 a and b ENSI-G03
DI-89	The licensee shall ensure that the safety case provides a clear understanding of the safety arguments, is suitably comprehensive and documented with a content and level of detail appropriate to the step reached in the disposal facility development.	Section 9 b and Section 11 d and i ENSI-G03
DI-90	The licensee shall ensure that the safety case provides clarity, substantiation and traceability of the assumptions, choices and decisions made.	Section 4.4 a to c, Section 9 c and Section 11 d and e ENSI-G03
DI-91	The licensee shall ensure that the safety case adequately reflects the factors (e.g. features, events and processes) that influence safety and their significance.	Article 33 NEO Section 9.2.1 c ENSI-G03
DI-92	The licensee shall identify all uncertainties significant to safety and shall demonstrate that these uncertainties are adequately taken into account in the safety case. As part of the safety case, the licensee shall describe a programme for uncertainty management.	Section 9 c, Section 9.2 b, Section 9.2.1 a and Section 9.2.2 c ENSI-G03
DI-93	The licensee shall ensure that the safety case shows that the principle of optimization has been addressed in relevant choices and decisions on the disposal system.	Section 4.4 ENSI-G03
DI-94	The licensee shall present as part of the safety case the programme, plans and provisions for closure of the disposal facility and for any post-closure activities. The programme, plans and provisions shall be revised and updated as appropriate.	Article 22 k NEA Article 42 NEO Section 7.6 and Section 9 e ENSI-G03

DI-95	The licensee shall describe in the safety case the management system, including the principles on which it is based, and how it will evolve during future phases of development, operation and closure of the disposal facility.	Section 11 ENSI-G03 ENSI-G07
DI-96	The licensee shall include in the safety case, subject to a graded approach, a synthesis of multiple lines of reasoning regarding post-closure safety and an evaluation of the level of confidence reached.	Section 9 ENSI-G03 Section 4.2 ENSI-G07
DI-97	The licensee shall update the safety case to reflect current knowledge and submit it to the regulatory body • in support of applications for major regulatory decisions; • as a result of major changes relevant to safety (e.g. in basic assumptions); • at least at regular (periodic) intervals as defined in the national legal and regulatory framework.	Section 9 ENSI-G03
DI-98	The licensee shall update the safety case to reflect as a minimum: • Changes to regulatory requirements and standards; • Results from surveillance programmes; • Changes to the radioactive waste inventory to be disposed of; • Results from analysis of operational occurrences and accidents; • Results of the periodic safety reviews; as soon as reasonably practicable and in accordance with the safety importance of the improved knowledge.	Article 33 NEO Section 9 c and e and Section 9.2 d ENSI-G03 ENSI-G08
DI-99	The licensee shall use the safety case as the basis for assessing the safety implications of changes to the disposal facility and system.	Article 65 NEA Article 40 NEO
DI-100	The licensee shall consider in the operational safety assessment, both occupational exposure and public exposure resulting from normal operation, and anticipated operational occurrences and possible accidents.	Section 9.1 ENSI-G03

DI-101	The licensee shall include in the post-closure safety assessment a scenario analysis that considers the possible features, events and processes that might affect the performance of the disposal system, including events of low probability.	Section 9.2.1 c ENSI-G03
DI-102	The licensee shall determine in the assessment whether adequate defence in depth has been provided, as appropriate, through a combination of several layers of protection (e.g. safety function provided by physical barriers, systems to protect the barriers, and administrative procedures) that would have to fail or to be bypassed before there could be any consequences for people or the environment.	Article 11 NEO Section 5.2.2 a and b ENSI-G03
DI-103	The licensee shall substantiate the timescale over which the safety assessment is carried out in the safety case.	Section 9.2.1 a to c ENSI-G03
DI-104	The licensee shall assess the possible evolution of the criticality hazard after closure in the light of long-term uncertainties.	Section 5.1 c, Section 9 c and Section 9.2.1 a ENSI-G03
DI-105	In the safety assessment, the licensee shall only use models and computer codes that have undergone verification and, to the extent possible, validation.	Section 9 c and Section 9.2.1 b ENSI-G03
DI-106	The licensee shall carry out at regular intervals a review of the operational and post-closure safety of the facility (periodic safety review – PSR), to confirm compliance with licensing requirements. The frequency of the review shall be established by the national legal and regulatory framework (e.g. every ten years).	Article 22 NEA Article 33 NEO Section 9 d ENSI-G03

DI-107	The licensee shall define, substantiate and submit to the regulator the scope of the Periodic Safety Review and shall ensure that, as a minimum, the following are taken into account in the PSR: • Review and analysis of operational experience; • Review of operating experience in radiation protection aspects; • Review of the waste acceptance criteria and waste quality controls; • Review of knowledge and experience of aspects affecting post-closure safety; • Review of the assumptions made in the safety case to confirm that they are still valid; • Review of compliance with current regulatory requirements. ...	Article 22 paragraph 2 f NEA Article 33 NEO Sections 6.1, 6.2, 7.2 and 7.6, Section 9.1 a, b, d and e, Section 9.3 d and Section 9.3.1 ENSI-G03
DI-108	The licensee shall document the results of the PSR, and derive and implement an action plan for all reasonably practicable improvements to safety.	Article 22 i NEA Article 41 and Annex 3 NEO Article 124 RPO