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Draft Safety Analysis Report for the Vrbina Krško LILW Repository

Section 5 Summary of Design Bases

DOCUMENT HISTORY

Revision:	Date of (previous) revision:	Brief description of changes from the previous version:	Notes:
1	May 2017	amendment of document following review	
2	January 2018	amendment of the document following review by an approved nuclear and radiation safety expert	
3	November 2018	amendment following SNSA review	
4	February 2019	amendment following SNSA review	
5	March 2019	supplementing of application	

CONTENTS

ABBREVIATIONS AND TERMS

DG: diesel generator

ICRP: International Commission on Radiological Protection

NRC: Nuclear Regulatory Commission, independent US agency

Postulated initiating event (PIE): an event that is identified as part of the design bases and that could initiate an anticipated operational occurrence or accident

5 SUMMARY OF DESIGN BASES

5.1 GENERAL

The design bases were drawn up in accordance with Annex 5 of the JV5 rulebook. [1] The design bases for the Vrbina LILW repository (environmental impact assessment phase) [2] were drawn up as an independent document in accordance with Annex 5 of the JV5 rulebook [2] and, in line with the development of the project, the investor's requirements and the requirements of the legislation, they constitute an upgrade to the previous design bases for the LILW repository at the potential site of Vrbina in the municipality of Krško, which were drafted by IBE d.d. in 2009 [3] and an upgrade to the design bases for the Vrbina LILW repository (environmental impact assessment phase), Revision 1. [4]

This section of the draft safety analysis report provides a general presentation of the design bases, and details are provided in later sub-sections. At the same time Section 5 of the draft safety analysis report and its sub-sections are structured a little differently from the design bases document, [2] as the section follows the content proposed in the SNSA guidelines for the preparation of the safety report. [5]

Section 2 of the design bases reference document [2] sets out the points of departure, purpose and scope of the design bases. Section 3 presents the disposal concept as set out in Revision C of the conceptual design, [6] while Section 4 sets out the general design conditions for the LILW repository.

Section 5 contains key data on the waste planned for disposal in the repository. The general requirements regarding waste are set out in Section 6 (of course, this waste will have to meet the waste acceptance criteria, which are presented in sub-section 11.3 of VP13 of this draft safety analysis report).

Section 7 of the design basis document [2] then presents the site (Vrbina) at which the repository is to be constructed. The site is described in terms of the different potential aspects of its impact on the repository and vice-versa, and the impact of the repository on the environment itself.

Section 8 examines in detail the repository scenarios/states presented, and the initiating events resulting in the respective scenarios. The design bases divide the scenarios into those during the operation of the repository, and those following its closure.

Another of the basic tasks of the design bases is to identify the structures, systems and components laid down by the JV5 rulebook. [1] These are divided according to groups of facilities at the repository, i.e. into sets of structures, systems and components (SSC) in disposal, technological, and administrative and service facilities, physical protection facilities, the external layout of infrastructural lines and connections, and monitoring facilities. As required by JV5 and the graded approach, SSCs are identified following an engineering assessment made by a group of specialists in different fields on the basis of safety analysis, and then classified according to safety criteria. They are divided into safety-related SSCs and non-safety-related SSCs. All SSCs are presented and described in detail in Section 6 (VP6) of this document, while the safety classification is given in Section 5.3 of this document.

The SSCs that have been made subject to special requirements up to this point (acquisition of environmental consent) are described in detail below (Section 11 of the design bases reference document [2]). The requirements are broken down into those relating to:

- operational limits and conditions,
- facilities and structures,
- seismic loads,
- architectural solutions, landscaping and human activities,
- technological systems,
- mechanical installations and equipment,
- electrical installations and equipment,
- computerised control and surveillance,
- telecommunications,
- the distribution of facilities, systems and devices,
- radiation protection and dose limits,
- environmental protection and operational monitoring,
- fire protection,
- flood-protection and protection against meteorological impacts,
- occupational health and safety,
- the physical security of facilities, restriction of access to facilities, and restrictions on the introduction and removal of materials,
- the provision of unobstructed access,
- safety analysis and emergency preparedness,
- functional analysis,
- documentation,
- transport of waste,
- other areas.

The requirements with regard to environmental loads are given in the following sections:

- radiation protection and dose limits,
- environmental protection and operational monitoring.

Further requirements concerning the revision of the design bases are set out at the end of the document (Section 12 of the design bases).

5.2 DESIGN BASES AND PRINCIPLES

5.2.1 DESIGN PRINCIPLES

The basic design principles for the LILW repository follow the recommendations contained in the fundamental safety principles, [7] which are also incorporated in the Resolution on nuclear and radiation safety [8] and the Resolution on the national programme for radioactive waste and spent nuclear fuel management. [9] The basic principles taken from the two resolutions and taken into account in the design of the LILW repository are as follows:

Principle 1: Responsibility for safety,
Principle 2: Role of government,
Principle 3: Leadership and management for safety,

Principle 4: Justification of facilities and activities,
Principle 5: Optimisation of protection,
Principle 6: Limitation of risks to individuals,
Principle 7: Protection of present and future generations,
Principle 8: Prevention of accidents,
Principle 9: Emergency preparedness and response,
Principle 10: Protective measures to mitigate existing or unregulated radiation risks.

During the project design phase, it was necessary to take account of the recommendations of the International Commission on Radiological Protection (ICRP) [10] and the recommendations contained in the IAEA's Disposal of Radioactive Waste document. [11]

The planned LILW repository also satisfies the following basic criteria:

– the repository is intended for the disposal of radioactive waste,
– the repository must isolate waste from the biosphere to the greatest possible extent and minimise the possibility and the consequences of inadvertent human intrusion,
– the repository must limit, minimise and retard the migration of radionuclides into the biosphere,
– the repository and the disposal concept must ensure that the quantity of radionuclides that can reach the biosphere is such that the impact on the environment and on people is acceptable (below the permitted limits) at all times.

All criteria and principles must be addressed using a graded approach.

In accordance with the JV5 rulebook, [1] a graded approach is an approach in which the processes for ensuring an adequate level of analysis, documentation and measures are commensurate with:

- their importance to safety, the control of nuclear materials and physical security,
- the magnitude of potential hazards,
- the phase of the facility's lifecycle,
- the method of use or the purpose of the facility,
- the characteristics of the facility,
- the importance of radiation and non-radiation hazards and other relevant factors.

The graded approach used in the document means that greater attention is given to important characteristics (i.e. they are designed or described in greater detail or more extensively) and less attention is paid to less important characteristics (i.e. they are designed or described in less detail). The graded approach also means that there is greater emphasis and focus on the description and design of SSCs during the phases of the construction and operation of the repository, and less on the processes of decommissioning, closure and long-term controls and maintenance, which will become more concrete as the project and the documentation is developed. For example, the decommissioning strategy and the relevant plans are adjusted to take account of the complexity of the facility, the type of radioactive waste within it, and phase of the facility's lifecycle in which the programme is being developed. The use the graded approach for the LILW repository, for example in design, means that there is no need to guarantee the basic safety function of subcriticality, as generally required by the JV5 rulebook. [1] In line with the graded approach, probabilistic design criteria are not applied to the LILW repository, and the safety classification was conducted on the basis of the results of safety analysis and an engineering assessment by a group of experts in various fields. The SSCs for the LILW repository are divided into safety-related SSCs and non-safety-related SSCs.

Because the graded approach principle is applied to the design process for the LILW repository, which is a nuclear facility the safety of which is based largely on passive safety functions, the requirements are laid down in such a way that the safety functions and systems, or the barriers for preventing radioactivity from spreading into the environment, are designed and used in such a manner that any accident would give rise to minor or insignificant consequences for the environment and for people.

The safety of the repository is demonstrated by means of safety analysis, [12], [13], which is incorporated into the safety report and is processed in detail within the framework of the safety analysis documentation. [14]

Under the requirement referred to in Article 3 of the JV5 rulebook, [1] the following principles must be adhered to when designing an LILW repository (application of the principles to an LILW repository is explained in brackets):

- defence-in-depth (multi-barrier systems – multiple SSCs perform the same function and multiple functions are used to achieve safety),
- single failure criterion (the safety analysis addresses the scenario of early failure of all engineered barriers),
- independence (individual SSCs are physically separate),
    - within the framework of the safety analysis individual SSCs are addressed as separate engineered barriers, each with its own properties,
- diversity (the same safety function is performed by different SSCs),
    - the same safety functions performed by various SSCs are disclosed in the safety analysis (Section 7.3.3.4.1) and in Table 5.6 of this section,
- redundancy (demonstrated via safety analysis – scenario of complete failure of engineered barriers, safety functions of individual barriers are duplicated),
- fail safe (all SSCs are designed so that, even if they fail, they do not present a danger to the facility itself),
- tested components (internationally tested practices and findings are applied, tested equipment or technology will be used when it exists), and
- graded approach (applied in accordance with international best practice and recommendations).

In line with the requirements referred to in Articles 7 and 8 of the JV5 rulebook, [1] and in line with the graded approach, the following must be in place for an LILW repository:

Basic safety function:

- containment of radioactive materials in solid and liquid form in all states of the facility, including under the normal evolution scenario, and
- the aforementioned design bases of SSCs.

5.2.1.1 General design bases

Under Article 4 of the JV5 rulebook, [1] the following general design bases are taken into account for an LILW repository.

The design bases [2] are part of the draft safety analysis report, which is in turn part of the environmental impact report [15] compiled as part of the process of acquiring preliminary consent on nuclear and radiation safety.

The following were required in the design bases:

- making a selection of the anticipated operational occurrences and design-basis events from among all the postulated initiating events in accordance with the second paragraph of Article 11 of the aforementioned rulebook that could have an impact on the safety of the radiation or nuclear facility and whose probability of occurrence is not negligible,
- taking steps to ensure that the safety provisions from the safety report are adhered to, with due regard to all phases of the facility (design, construction, trial operation, operation, termination of operation, standby phase, decommissioning, closure or the completion of any mining work). In the case of long-term controls of repositories, these steps are taken by the entity responsible for long-term controls,
- providing evidence that design standards and materials adequate for ensuring safe operation are used for the facility, taking into account the envisaged service life of the facility and, if the facility is a repository, the post-closure period as well, and for as long as the repository is obliged to perform an isolating function,
- taking account of the ageing of SSCs and the need to ensure that safety functions are performed throughout the service life and, if the facility is a repository, the post-closure period as well, and measures planned for the maintenance, testing and inspection of SSCs;
- ensuring that excessive exposure to ionising radiation owing to design-basis accidents and Category A beyond-design-basis accidents will be prevented, or mitigated if prevention fails, such that there is no need for protective measures such as iodine prophylaxis, culls or evacuation,
- ensuring through design solutions at all stages of the facility (including decommissioning) that the lowest possible quantities of radioactive waste are generated with the lowest possible radioactivity,
- ensuring that radiation doses to which the general public and workers (individual and collective doses) are exposed and the impacts on the environment at all stages of the facility (including decommissioning) do not exceed the prescribed limits and are so small that this can reasonably be achieved,
- providing protection against the radiological consequences of the facility to an extent that the health or life of no individual is exposed to a risk greater than the risk that would exist if the facility were not built,
- providing multi-level defence, with due adherence to the principle of defence-in-depth, including by deploying a series of physical barriers to prevent abnormal releases of radioactive materials into the environment (or, if prevention is unsuccessful, the mitigation of those releases), and to ensure that the barriers are highly effective through the combination of safety functions,
- ensuring that a threat to the integrity of individual physical barriers is prevented,
- ensuring that individual barriers do not fail while performing their functions,
- ensuring that no physical barrier fails as a result of the failure of another physical barrier,
- ensuring that the surveillance and warning system meets the operational needs of the facility, and provides operational personnel with a good understanding and enables them to respond effectively to design-basis events and accidents,
- ensuring that the design bases contain fire safety requirements prepared on the basis of an analysis of fire risk and with the application of the defence-in-depth principle,
- ensuring, in the case of a radioactive waste repository, that contamination of the environment with radioactive materials and radiation does not exceed the prescribed levels under the normal evolution scenario.

5.2.2 SELECTION AND CLASSIFICATION OF POSTULATED INITIATING EVENTS

The scenarios for the LILW repository have been designed in accordance with international recommendations [16], [17] and best practice. A more detailed description of the set of scenarios is given in the reports on the implementation of the safety analysis and recalculations in the Operational Safety Assessment Report for Scenarios, Models and Results of Calculations [18] for the operating period, and in the Report on initial scenarios under post-closure conditions [19] for the post-closure period. A summary of the methodology for selecting scenarios, and the selection process itself, is given below.

The main criterion for classifying the postulated initiating events and scenario development was international practice with the established lists of initiating events, and expert judgment.

5.2.3 ANALYSIS OF POSTULATED INITIATING EVENTS

A postulated initiating event is an event that is identified as part of the design bases and that could initiate an anticipated operating occurrence or accident. [1]

In line with the recommendations contained in the Practical guidelines on the content of the safety report, [5] the selection and classification of postulated initiating events is placed into two sub-groups:

- initiating events for the operation, closure and decommissioning of the repository,
- definition of the features, events, processes (FEPs) for the repository in the post-closure period.

The list of postulated initiating events recommended by the IAEA in the GSG -3 [16] was used for selecting initiating events during the operation (which also includes the standby phase), closure and decommissioning of the repository, and was supplemented by the anticipated operating occurrences as defined in the Reference documents: Operation. [20]

A special database of FEPs was designed for the selection of post-closure scenarios, which is described in detail in the Report on initial scenarios under post-closure conditions, [19] which contains a list of FEPs produced under the ISAM project. [21] The FEPs can be viewed as a set of postulated initiating events for the post-closure phase of the repository. The FEPs have been reviewed, and those of no relevance to Vrbina LILW repository have been eliminated, as described in detail in the safety analysis in the Report on initial scenarios under post-closure conditions, Part 1.8, Technical report ARAO, EISFI-TR-(11)-07. Rev. 1. [18] Suitable scenarios were then developed from the FEPs that remained.

5.2.4 SELECTION OF SCENARIOS FOR PERIOD OF OPERATION

The repository’s period of operation consists of the waste disposal period, and the standby phase when no waste disposal is carried out. The standby phase is described in detail and defined in Section 9.13 of this document.

For the LILW repository’s period of operation, there is a distinction between the normal evolution scenario, which envisages that all events and processes evolve in accordance with plans and that the characteristics of individual SSCs do not deviate from the plans, [14] and the abnormal evolution scenarios (anticipated operational occurrences and accidents) that may occur at the repository and during transport.

The scenario of normal operation and the normal evolution of events for the period of waste disposal during operation consists of the following course of events and processes:

- Waste is conditioned for disposal at Krško NPP, and packed into FPs that meet the acceptance criteria.
- The waste is transported to the LILW repository (Krško NPP is responsible as the waste conditioner for disposal).
- The waste is received at the repository, visual controls are conducted for the FP and radiation is measured on the surface of the FP, and the documentation is checked.
- The disposal process continues after all the requirements have been met. The FP is transported to the roof and disposal silo, where it is unloaded using a gantry crane into its predetermined position in the disposal silo.
- A drainage system is in operation in the silo during operation to collect and remove any seep water.
- Under Scenario SA.3, after the Slovenian half of the operating waste is disposed of, the standby phase commences as a sub-phase of operation (although without FPs being disposed of).
- After the silo has been filled (or even already operation), the voids between the containers and the wall of the silo are filled with backfill material. A concrete slab is laid on top of the vault.
- A clay layer is then placed on top of this, providing an additional barrier between the silo and the Quaternary aquifer (and parts of the silo above ground level are demolished as appropriate).

The scenario of normal operation and the normal evolution of events for the standby phase consists of the following course of events and processes:

- Waste is stored at the site of the waste owner/generator, and is not disposed of at the LILW repository.
- Waste already disposed is brought to a state that meets nuclear and radiation requirements and the requirements of a long-term standby state.
- A drainage system is in operation in the silo during operation to collect and remove any seep water.
- Systems and devices for the standby phase are prepared.
- The entire repository is brought into a state that will ensure safe and economical standby phase operation.
- Monitoring is conducted.
- Activities in connection with controls of the ageing process and operating experience feedback are carried out.

Anticipated operational occurrences (abnormal operation) that will be managed via internal rulebooks and instructions, and are assessed as having no impact on nuclear and radiation safety (no radiological consequences) are as follows (operational occurrences that can arise during the standby phase are specifically denoted):

- loss of external electrical power (may occur during standby phase) (no impact on other SSCs is envisaged),
- failure of a vehicle transporting LILW to the repository site (no impact on other SSCs is envisaged),
- failure of a crane above the silo (the failure may lead to the container drop scenario described below; if no drop occurs, no impact on other SSCs is envisaged),

- failure of the pump station in the silo and by the control pool (may occur during standby phase) (no impact on other SSCs is envisaged),
- failure of the fire alarm system (may occur during standby phase) (no impact on other SSCs is envisaged),
- failure of the fire protection system (may occur during standby phase) (no impact on other SSCs is envisaged),
- failure of the system for recording data on LILW (no impact on other SSCs is envisaged),
- failure of devices for measuring releases and radiological monitoring (may occur during standby phase) (no impact on other SSCs is envisaged), and
- rejection of an LILW shipment (no impact on other SSCs is envisaged).

Anticipated operational occurrences further include anomalies in filling voids in the silo, minor collisions of transport equipment and failures of auxiliary systems (e.g. heating).

Another anticipated operational occurrence is an authorised dose limit being exceeded (no impact on other SSCs is envisaged), which has a low probability of occurrence given the activities at the LILW repository.

The following are design-basis emergencies and accidents (design-basis events), which have an extremely low probability of occurrence:

- fire (may occur during standby phase),
- container drop,
- airplane crash (including explosion and fire) (may occur during standby phase),
- terrorist attack (may occur during standby phase),
  earthquake (followed by operational shutdown and checking of SSCs) (may occur during standby phase).

In accordance with the requirements of the PS 1.03 guidelines, [5], it is necessary to analyse the following for the cited events:

- the functioning of systems and tools for the handling of radioactive waste (Section 6 of this draft safety analysis report),
- the functioning of systems and tools for the containment of releases into the environment (Section 6 of this draft safety analysis report),
- the functioning of systems and tools for the monitoring of releases into the environment (Section 6 of this draft safety analysis report),
- the functionality of engineered and geological barriers (Section 7 of this draft safety analysis report),
- the inspection and maintenance programme (Section 9 of this draft safety analysis report).

5.2.4.1 Fire scenario

As a scenario, fire is treated as the consequence of several initiating events. It is divided into two sub-scenarios. The first is a fire at the technological facility, while the second is a fire caused by an airplane crashing into the silo (in combination with an explosion). The conservative assumption is that the fire engulfs packages from the most active waste streams from Krško NPP and the CSRAO. The impact of the event is assessed for workers and for members of the general public in the area. The safety analysis defines the scenario in greater detail within the framework of SSC planning, and appropriate design solutions to mitigate the consequences of the scenario should be defined.

In the event of a fire described in detail in Section 7 of this document, damage to SSC O1 (final package) will occur.

5.2.4.2 Container drop scenario

The scenario of a container drop includes three sub-scenarios:

- a container drop from a height of 3 m inside the technological facility,
- a container drop from a height of 50 m or 35 m into the silo,
- the impact of the events is assessed for workers, and for members of the general public in the area.

In the event of a container drop damage can occur to SSC O3 (silo), particularly in the event of a container drop into an empty silo. In this event it is necessary to examine the damage incurred, and to take the necessary remedial action for the SSC. In this event there could also be damage to SSC O4 (drainage system), any damage to which needs to be examined and remedied. In all drops damage to SSC O1 (final package) will occur. In all drops damage to SSCs needs to be examined and remedied.

5.2.4.3 Explosion scenario

The explosion scenario also includes the initiating events of a terrorist attack and an airplane crash. In the event of a terrorist attack, it is assumed that the terrorists will circumvent the security system and place a significant quantity of explosives inside the technological facility. In the event of an airplane crash, the assumption is that a mid-size transport airplane or large military airplane crashes into the technological facility. A worst case scenario is assumed for the inventory located at the technological facility in terms of quantity and quality. The doses for individuals at varying distances from the explosion are estimated.

In the event of an explosion, the following SSCs could be damaged:

- O1 – final package,
- O2 – backfill,
- O3 – silo,
- O4 – drainage system.

In the event of damage, it is necessary to examine all SSCs for damage and to take appropriate remedial action.

5.2.4.4 Combination of events

Given that the LILW repository is a relatively simple nuclear facility, and with due regard to the graded approach, various events and scenarios were analysed as part of the safety analysis (Section 7 of this document), where they can be said to be marginal, and their consequences constitute the upper envelope of the impact that such a facility could have.

During the operating phase of the LILW repository, a combination of the earthquake and container drop events could be expected. From a nuclear and radiation safety standpoint, only the container drop event can lead to the release of radionuclides at the time that this combined event occurs, while damage to the silo structure could lead to release after the event (after a longer period of time). As people will be present during repository operation, the damage is assessed in this case and appropriate remedial action taken (remediation of the container and silo or the flooding of the entire damaged layer, together with the container, with concrete). Similarly, the airplane crash scenario, which involves collision, explosion and fire, represents the upper limit of the impact of a combination of events during operation.

In the repository's post-closure phase, the scenario of the failure of engineered barriers replaces this scenario as the upper limit of the impact of the repository on the environment and on people. In this case, it is envisaged that none of the engineered barriers continues to perform its containment function (physical containment). This scenario involves a combination of events, when the key role in providing barriers is assumed by the natural environment in which the repository is located.

5.2.5 SELECTION OF SCENARIOS OF THE POST-CLOSURE EVOLUTION OF THE REPOSITORY

The nominal scenario (the scenario of the normal evolution of events at the LILW repository after closure) consists of the following course of events and processes:

- The phase of active and passive controls of the disposal units, which lasts 300 years, begins after closure.
- The engineered barriers gradually begin to degrade.
- It is assumed that there is a family residing in a village in the vicinity of the repository (100 m), and they use a well drilled into the Quaternary aquifer for their own water supply.

The nominal scenario also contains several sub-scenarios:

- an alternate model of degradation of the engineered barriers, where the barriers fail in succession,
- a biosphere without a well (all water required is taken from the river),
- a biosphere in which water from the well is used to irrigate crops,
- a biosphere in which water from the well is used for the watering of livestock.

The post-closure alternate evolution scenarios are as follows:

- early failure of engineered barriers,
- river meandering and surface erosion,
- inadvertent human intrusion,
- change to hydrological conditions.

5.2.5.1 Scenario of early failure of engineered barriers

This scenario presents a large number of potential initiating FEPs that could affect the ability to isolate radioactive waste and to contain radionuclides. These FEPs incorporate the following initiating events:

- a major beyond-design-basis earthquake event (earthquake scenario),
- faults in manufacture or construction, and
- anomalous operation.

The scenario of early failure is evaluated in the same way as the nominal scenario, but with the assumption of a very fast degradation of the physical properties of the engineered components. This begins at the end of institutional controls and, after one year, all the physical properties of the engineered barriers have moved to a state of failure. This conservative assumption is made on the basis that it includes the effects of various events and processes that could affect the rate of degradation of the SSCs at the repository. The scenario is presented in more detail in Section 7.3.4 of this draft safety analysis report.

5.2.5.2 Scenario of river meandering and surface erosion

Natural forces or human activity may, in the future, lead to changes in the course of the Sava, which could then flow over the repository. This would lead to the erosion of part of the Quaternary stratum, and to changes in the speed and direction of the water flow in the Quaternary aquifer. From a geological point of view, it is impossible for erosion to be so strong over a period of 10,000 years that it would reach the depth of the silo and the disposed waste. The main effect of any change in the flow of the river is a change to the speed and direction of flow of the groundwater around (and through) the repository. The scenario is presented in more detail in Section 7.3.6.4 of this draft safety analysis report.

5.2.5.3 Scenario of inadvertent human intrusion

Given the site of the repository and the disposal concept (below the water table), the probability of inadvertent human intrusion is very low. The main possible scenario is intrusion by drilling, which could occur after the end of institutional controls (300 years after closure). An estimate is made of the dose sustained by the driller, and by a member of the public living in the area after drilling.

5.2.5.4 Scenario of change to hydrological conditions

A large number of FEPs lead to a change in regional hydrological conditions, and must be taken into account in the safety assessment. These FEPs are:

- natural or man-made climate changes,
- construction of dams or other projects on the Sava,
- other indirect measures that change the behaviour of the groundwater at the site (e.g. the drilling of boreholes in the vicinity of the repository site, digging of drainage ditches, etc.),
- a flood scenario.

The key effects of these changes on the repository are a change to the direction and speed of the flow in the nearfield of the repository and the Quaternary aquifer. The scenario is presented in more detail in Section 7.3.6.5 of this draft safety analysis report.

5.2.6 INVENTORY OF RADIOACTIVE WASTE, REPOSITORY CAPACITY AND CAPACITY OF AUXILIARY SYSTEMS

5.2.6.1 General requirements regarding waste

I. Radiation and nuclear safety regulatory requirements

1) Chapter 4.4 of ReNPRRO16–25 [22] provides that, under the baseline scenario, half the LILW from Krško NPP (LILW from the operation and decommissioning of Krško NPP and other LILW such as replaced and removed equipment, etc.) will be disposed of at the Vrbina repository, unless agreement is reached with Croatia regarding joint disposal. In addition,

LILW from the CSRAO at Brinje, LILW from the decommissioning of the CSRAO and the TRIGA Mark II reactor, and LILW generated by the operation and closure of the repository itself will also be disposed of at the repository. If agreement is reached with Croatia under BHRNEK, all the LILW from Krško NPP (LILW from the operation and decommissioning of Krško NPP and other LILW such as replaced and removed equipment, etc.), together with LILW from the CSRAO at Brinje, LILW from the decommissioning of the CSRAO and the TRIGA Mark II reactor and the LILW generated from the operation and closure of the repository itself will be disposed of at the Vrbina repository under the expanded scenario. The repository must be designed in such a way that all types of LILW produced in Slovenia can be disposed of at it; the only (minor) exceptions are smaller quantities of long-lived radioactive waste or other radioactive waste whose disposal would entail disproportionately complex and costly procedures.

The regulatory requirement has been met by the description in the introduction and Section 2.4.1 of VP2 on the description of the repository, in Section 6 (VP6) on the compliance of repository system, and in Section 11 (VP11) of this document, where the waste acceptance criteria (WACs) are cited.

2) Article 93 of the ZVISJV [23] provides that holders of radioactive waste and spent fuel are required to ensure that:

- they manage the radioactive waste and spent fuel in the prescribed manner, and
- they avoid shifting the burden of disposing of radioactive waste and spent fuel to future generations as far as possible.

Moreover, a holder of radioactive waste and spent fuel is required to forward information on its generation to the central radioactive waste and spent fuel registry.

The regulatory requirement with regard to shifting the burden of disposing of radioactive waste to future generations has been met through clearly defined objectives and the timetable for investing in the construction and operation of the repository set out in several sections of this document, in particular VP1, VP2, VP9 and VP11. The requirement that radioactive waste be handled in the prescribed manner is primarily taken into account in VP11, which sets out the relevant skills for workers, the administration and updating of procedures and records, and regular reporting. The prescribed manner of handling is also set out in the aforementioned section within the framework of the WACs.

3) Article 4(2) of the JV7 rulebook [24] provides that solid radioactive waste should be classified into the following categories, according to the level and type of radioactivity:

1. transitional radioactive waste,
2. very low-level radioactive waste,
3. low- and intermediate-level radioactive waste (LILW):
3.1 short-lived LILW,
3.2 long-lived LILW,
4. high-level radioactive waste (HLW),
5. radioactive waste containing naturally occurring radionuclides that are produced in the extraction and processing of nuclear mineral raw materials or in other industrial processes and that are not considered sealed sources of radiation under the regulation governing the use of radioactive sources and radiation practices.

Similarly, Article 18(3) of the JV7 rulebook [24] provides that only radioactive waste that meets the acceptance criteria for disposal may be disposed of.

Proper classification is ensured at current holders of waste in accordance with the requirements of the JV7 rulebook [24] in all the prescribed procedures for conditioning for disposal, and within the framework of the WACs referred to in VP11, where the criteria and conditions are set out in detail to allow only the disposal of radioactive waste in accordance with the aforementioned criteria.

4) Annex 5, Section 11 of the JV5 rulebook [1] lays down the conditions that apply to both storage facilities and repositories. In addition to the conditions referred to in points 1 to 7 of the aforementioned annex, a repository and any facility engaged in conditioning or processing waste prior to its disposal should also, where required, meet the other requirements referred to in the design bases for radioactive waste storage facilities as referred to in Annex 3 of the aforementioned rulebook.

   Annex 3, Section 2 provides, in relation to containment barriers and systems, that radioactive waste should be packaged so as to allow safe handling without releases of radioactivity into the environment or irradiation that exceed the allowable limits. Each package should be designed to last at least the entire service life of the repository.

   Annex 3, Section 3 provides, in relation to the handling of radioactive waste packages, that the design should provide for appropriate equipment and packaging for the handling of damaged radioactive waste packages within a reasonable time following detection of the damage.

   The operator's written procedures describing the method of acceptance of radioactive waste should also include instructions for safe handling of radioactive waste that does not meet the acceptance criteria for disposal.

The requirements with regard to containment barriers and systems and the handling of radioactive waste packages are taken into account in Section 6 of this document (VP6), which describes the solutions' compliance with the project and the requirements of the design bases. The requirement regarding the instructions of how to safely handle radioactive waste that does not meet the WACs will finally be taken into account in the preparation of written procedures for the trial operation and full operation of the repository.

II. International standards, principles and directives

During the design phase, due regard should be given, where relevant, to the following IAEA and WENRA safety standards:

IAEA:

1) Safety Fundamentals SF1: Fundamental Safety Principles (2006); (2.2 The fundamental safety objectives apply to all facilities and activities, and to all phases of the lifecycle of a facility or radiation source, including planning, siting, design, manufacturing, construction, trial operation and operation, as well as decommissioning and closure. This includes the associated transport of radioactive material and management of radioactive waste.

2) Safety Requirements

- General Safety Requirements GRS Part 5: Predisposal Management of Radioactive Waste (2009) lays down the responsibilities associated with the predisposal management of radioactive waste, the steps that must be taken in the predisposal management of radioactive waste, and the development and operation of facilities in which predisposal radioactive waste management activities must be carried out. Under the requirements set out in Chapter 4, all waste must be properly identified, characterised, classified, processed and, where required, stored in accordance with the acceptance criteria, records maintained of waste generated, and steps taken to ensure that waste is produced in the smallest possible quantities.

3) Safety Guides

- General Safety Guide GS-G-3.3: The Management System for the Processing, Handling and Storage of Radioactive Waste (2008) puts forward proposals for establishing a management system for the conditioning, handling and storage of RW.

- General Safety Guide GS-G-3.4: The Management System for the Disposal of Radioactive Waste (2008) puts forward proposals for the establishment of a management system at all envisaged phases of a repository's lifecycle.

WENRA:
- Radioactive Waste Disposal Facilities Safety Reference Levels. [25] Under point 2.1.5, DI-20, the operator of a repository is expected to adequately ensure, check and document data on the inventory of waste accepted and disposed of at the repository, at all stages of the facility's lifecycle. Under point 2.2.3, DI-34, the operator of a repository must, during operation, take into account the characteristics of the waste, such as data on radioactivity and the heat and gas generated.

III. Recommendations and studies

1) Chapter 5.2.6 of PS 1.03 [5] provides that the capacity of the repository and of the auxiliary processing and storage facilities must be given, along with the timetable of operation, on the basis of the existing and expected radioactive waste inventory in Slovenia, and taking into account the mass, volume and properties of the waste and other data.

The radioactive waste dynamics, quantities, types and classes must be described:
– upon acceptance, for every processing operation and for disposal (primary RW);
– the generation of waste from the operation of the repository (secondary RW);
– waste that will be generated from the decommissioning of the repository facilities.

For all waste types and classes of the origins listed above, all data that makes it possible to establish compliance with the acceptance criteria, the individual process involved, the package, the disposal unit and the repository as a whole must be provided.

In addition to this data, data on waste must also provide the values used in the safety analysis.

For radioactive waste generated during the performance of an activity at the repository, data on the locations of their generation during repository operation must also be given.

For radioactive waste that will be generated during the decommissioning of the facilities or the closure of the repository, information on the decommissioning activities that will generate the waste must also be provided.

Chapter 11.1 of PS 1.03 (acceptance criteria) should be determined as part of the operational limits and conditions. The measures to be taken in the event that waste received does not meet the acceptance criteria must be stated. Acceptance criteria shall be drawn up for each radioactive waste management phase at the repository, such as: receipt, processing, temporary storage, package, disposal unit, repository.

The existing and anticipated inventory of radioactive waste in Slovenia is provided in Section 5.2.6.2. The capacity of the repository is provided in Sections 2.4.1 (VP2), 5.2.6.2.4 (VP5) and 9.1.1.1. (VP9), where the dynamics of the operation of the repository are also presented. VP9 and VP11 also provide data on waste generation centres during the operation of the repository.

Section 9.5.1. defines the rejection of a consignment of LILW as an abnormal operating state (anticipated operational occurrences), with the measure of rejecting a consignment of this type and returning it to the LILW conditioning site for the purpose of repeat controls and remediation of the containers as necessary.

IV. Spatial planning acts, opinions and design conditions

The Decree on the DPN [26] provides that a nuclear facility is to be constructed for the permanent disposal of low- and intermediate-level radioactive waste produced in Slovenia, with a disposal capacity of 9,400 m^3, with an option to expand the repository's disposal capacity.

The requirement is taken into account and demonstrated in several sections of the draft safety analysis report that set out the disposal capacity of the repository, such as 2.4.1 (VP2), 5.2.6.2.4 (VP5) and 9.1.1.1 (VP9).

V. Investor's requirements

1) In Feasibility Study Rev. C, [27] in accordance with the guidelines of the disposition for the drafting of a feasibility study and with due regard to the envisaged extension of the service life of Krško NPP, half the entire quantity of waste to be generated at Krško NPP by the end of the extended service life (2043) is taken to be the basic quantity of LILW that will have to be disposed of (design quantity), with half the quantity of waste from decommissioning and the existing figure for institutional waste being added to this quantity. The data on the quantities of LILW from Krško NPP is taken from the Preliminary Decommissioning Plan NPP Krško, Rev. 5. [28]

The requirements set out in Feasibility Study Rev. C were taken into account in the production of the conceptual design [6] and other reference documents of the draft safety analysis report, e.g. [28], [29], [30], and were additionally taken into account and clarified in several sections of the draft safety analysis report, where the capacity and dynamics of the repository (VP2 and VP9), and the operational limits and conditions including the acceptance criteria (VP11) are described.

5.2.6.2 Basic information on LILW

Ionising radiation is harmful to living creatures; radioactive waste must therefore be managed in such a way as to prevent people and the environment from being exposed to excessive levels of radiation. We have to ensure that radioactive waste does not cause direct radiation and to prevent contamination of the environment with radionuclides.

As the basic objective of RW and SF management, the individual and collective protection of people and the environment applies to all facilities and activities and all phases of operation of a nuclear or radiation facility or radiation source, including planning, siting, design, construction, operation, standby phase, decommissioning, closure and, in the case of a repository, long-term controls and maintenance. The transport of RW and SF must also be included.

To achieve the basic objective of RW and SF management, safe handling, retention and storage of all radioactive waste and spent fuel at all phases of their existence shall be followed, in accordance with the timetable, by the appropriate permanent disposal solutions. The procedures listed must be carried out efficiently, cost-effectively, transparently and in line with the legislation.

The operation of Krško NPP accounts for the bulk of the radioactive LILW produced in Slovenia, although LILW is also generated by industry, medicine, research institutions and the TRIGA research reactor. A large proportion of the waste will also be generated by the decommissioning of Krško NPP, and a lesser proportion by the decommissioning of the TRIGA research reactor, the CSRAO and the LILW repository itself, and the process of conditioning waste for disposal (which will take place at Krško NPP).

Waste disposed of at the LILW repository at Vrbina, Krško in accordance with the acceptance criteria will come from the following sources:

- Krško NPP operation,
- the decommissioning of Krško NPP,
- the decommissioning of the TRIGA research reactor,
- waste stored at the central radioactive waste storage facility at Brinje and waste generated by the decommissioning of that facility,
- waste from operation of the repository and the conditioning of waste at Krško NPP for subsequent disposal,
- waste from the decommissioning of disposal facilities and systems at Vrbina and the decommissioning of facilities for the conditioning of waste at Krško NPP for subsequent disposal.

The design solution for the repository envisages the provision of capacity for the disposal of half the entire expected quantity of LILW from Krško NPP operation and decommissioning and the entire quantity of LILW stored at the central radioactive waste storage facility at Brinje and waste from that facility's decommissioning, the entire quantity of LILW from the decommissioning of the TRIGA reactor, the entire quantity of LILW produced from the conditioning of waste at Krško NPP for subsequent disposal at the repository, and the entire quantity of LILW generated by the operation and decommissioning of the repository itself.

The capacity of the repository is given in Sections 2.4.1 and 5.2.6.2.4 of this document; reference is also made in VP5 to the fact that capacity can be further expanded with the construction of additional silos. The Decree on the detailed plan of national importance for a low- and intermediate-level waste repository at Vrbina, Municipality of Krško [26] provides that the repository should be constructed with a disposal capacity of 9,400 m^3 of waste generated in Slovenia. The disposal capacity was determined on the basis of waste quantity estimates applicable at the time and produced for waste unpackaged and unconditioned for disposal. [31] Following updated estimates of the stored volume of existing LILW, projections of the generation of additional LILW from the operation and decommissioning of nuclear facilities, the envisaged conditioning of waste for disposal, and modifications to the envisaged disposal container (the N3 container has been replaced by the N2 container), an estimate was produced of the waste disposed of after being generated in Slovenia (Section 5.2.6.2.4). The disposal capacity of the repository now totals 990 N2 disposal containers or 12,157 m^3 (990 containers x 12.28 m^3 gross volume per container) and meets the requirements of the NSP. [25]

Estimates of the quantity of waste produced are based on existing sources, such as databases on waste already produced and stored, [32] decommissioning programmes or plans, and an estimate of future waste generation, based on assumptions regarding the history of operation and the processing procedures and volume reduction procedures used, and also containing a low degree of conservativeness. The estimated quantities of waste from Krško NPP, from the decommissioning of disposal facilities and systems at Vrbina and from the conditioning of waste for disposal at Krško NPP also include a portion of the waste for which Croatia is responsible under the Treaty between the Government of the Republic of Slovenia and the Government of the Republic of Croatia on the regulation of status and other legal relations regarding investment in and the exploitation and decommissioning of Krško nuclear power plant (BHRNEK). [33] The document highlights where the Croatian portion of the waste is not included.

The waste quantities presented correspond to the waste quantities currently located at the Krško NPP and CSRAO storage facilities, an estimate of the operating LILW at Krško NPP and the CSRAO by the end of the envisaged service life, and the estimated quantities of LILW to be generated by the decommissioning of nuclear facilities. They do not include changes to volumes resulting from processing and conditioning procedures in accordance with the acceptance criteria for disposal at the LILW repository at Vrbina, Krško. The final quantities of LILW disposed of may differ on account of different procedures of conditioning for disposal and packing into final packages.

Given the current timetable for the decommissioning of the dry container storage facility (beginning of 2103) and the disposal of LILW from Krško NPP at the Vrbina repository, LILW generated by the decommissioning of the dry container storage facility or by the repackaging of spent fuel is expected to be disposed of with spent fuel from Krško NPP and high-level radioactive waste from the decommissioning of Krško NPP (the disposal of this LILW is one of the boundary conditions in the study of the disposal of spent fuel and high-level radioactive waste being drafted as part of the third revised edition of the Programme for the Disposal of RW and SF from Krško NPP. [33]

5.2.6.2.1 Conditioning of LILW for disposal

In accordance with the third paragraph of Article 122 and the fifth and sixth paragraphs of Article 121 of the ZVISJV-1, [34] the ARAO is responsible for conditioning waste, although the waste conditioning process itself is not part of the ARAO project. In connection with the conditioning of LILW for disposal, Krško NPP compiled conceptual design documents entitled Canopy for handling equipment and consignments of radioactive freight and Technical support centre, and also built and began using the first phase of the facility. The second phase of the facility could also contain equipment for conditioning waste for disposal, and for activities for the supply of empty containers, internal transport of containers, recording of the properties of primary packages of LILW, the insertion of packages in disposal containers, the fitting of covers on containers, the backfilling of voids, exit storage, exit controls and transportation from Krško NPP to the repository. The ARAO is expected to outsource the conditioning of waste for disposal, and to exercise its controls of the conditions via the fulfilment of the acceptance criteria.

All waste that satisfies the acceptance criteria will be inserted into Type N2 standard disposal containers before disposal. Inserting waste packages into disposal containers and conditioning for disposal will be fully implemented at Krško NPP. Having regard for the available data on waste and the preliminary acceptance criteria described in Section 11 of this document (VP11), it was assessed on the basis of the safety analysis and analysis in preliminary phases of the production of the design output that compliance with the majority of the acceptance criteria can be achieved by inserting the packages of LILW into disposal containers. The remaining non-compliance will be eliminated by additional conditioning procedures, [30], [6] as described in the section on LILW from Krško NPP.

Waste in primary storage packages will be inserted in disposal containers in accordance with the working procedures at the conditioning facility. The filled container will be fitted with a cover, and fixed with special anchors and screws. The remaining void space in the container will be filled with backfill mortar through an opening in the cover, and the cover will be filled with a sealant for expansion and swelling. The properties and methods of the filling of the container are presented in detail in Section 6.2.1.1 G1 final package (VP6).

The envisaged procedures for the processing of LILW before disposal are presented in the remainder of this sub-section in terms of the source of the LILW.

Supervision of the process of filling disposal containers and checking the compliance of filled containers with the waste acceptance criteria will be carried out by ARAO at Krško NPP in accordance with the written procedures.

Compliance with the requirements for transportation will be checked by Krško NPP or the transporter of containers from Krško NPP to the repository. This checking will also be carried out at Krško NPP. [6], [9]

5.2.6.2.2 LILW from Krško NPP

The waste quantities apply to the period of Krško NPP operation up to 2043 based on the SAC&WAC Inventory Report [30], [35] (data on inventory for which there is no data in the Krško NPP database was conservatively assumed and estimated on the basis of other decommissioning programmes; the resources are presented in detail in the reference document), the inspection documents and their supplements, [36] the SNSA annual reports on ionising radiation protection and nuclear safety in Slovenia, [32] and the Preliminary Krško NPP Decommissioning Plan (PDP). [28] The design quantity of the disposal containers has been determined on the basis of the conceptual design, [6]

and the characteristics of the waste have been determined on the basis of current state of the inventory and measurements at Krško NPP. The quantity of other unmeasured radionuclides has been determined on the basis of scaling factors developed at Krško NPP following an analysis of individual samples, and on the basis of data from the literature, e.g. for beta emitters such as C-14, Cl-36 and Ni-59, which have not yet been measured in waste from the operation of Krško NPP, factors determined at the SKB organisation from Sweden have been used. [30] The isotopic composition of waste from Krško NPP operation is well known, while there are currently still several unknowns regarding waste from Krško NPP decommissioning (these will be finally removed when individual components are being demolished and dismantled at Krško NPP).

Over the last ten years, up to around 40 m^3 or less of waste has been generated annually at Krško NPP, with volumes being additionally reduced through processing. In past years, the volume of LILW generated at Krško NPP has been reduced using methods for reducing volume, such as compression, supercompacting, drying, incineration and melting, so that 2,271 m^3 of solid LILW was being stored at the storage facility by the end of 2016, with a total gamma activity of 17.1 TBq and total alpha activity of 0.025 TBq. Waste intended for incineration and melting is separated and, owing to a lack of space, temporarily moved to a decontamination building, where 260 packages of compressible LILW prepared for incineration were also being stored at the end of 2016. [9], [37]

An additional 1,001.9 m^3 of contaminated equipment (including two old steam generators) was being stored in the storage area for old steam generators at the end of 2014. [37]

5.2.6.2.2.1 ***LILW from the operation of Krško NPP***

If the lifetime of Krško NPP is extended to 2043, and based on the previous trend in the generation of operating LILW over the last few years and the continuation of the treatment and processing with the aim of reducing the volume of RW generated and existent RW, the estimated total quantity of operating waste generated amounts to 3,612 m^3 with a total activity of 124 TBq. This estimate does not include waste stored in the area for the storage of old steam generators. On the basis of the SAC&WAC reports [30], [36] and the preliminary Krško NPP decommissioning plan, [28] this waste is included in the waste quantities from Krško NPP decommissioning. The entire quantity of containers, encompassing the Slovenian and Croatian portions of LILW for disposal from Krško NPP operation, amounts to 1,067 N2 containers, while the design quantity of containers, which includes only the Slovenian half of LILW from Krško NPP operation, amounts to 533 N2 containers. [6]

The Type N2 container allows for the disposal of all classes of LILW from Krško NPP operation, of which spent ion exchange resins, evaporator concentrates and sediments from collectors require additional attention on account of the risk of corrosion, while with spent ion exchange resins there is also the issue of swelling in contact with water, which is only possible for those subjected to IDDS processing. The risk of corrosion can be mitigated by processing the waste to adjust its pH.

There are two options proposed for the additional processing of waste from ion exchange resins in connection with swelling:

- during final conditioning for disposal, sufficient voids in the final package (container) are provided to compensate for the increased volume of the ion exchange resins caused by swelling,
- repackaging before conditioning for disposal in the form of waste that has no potential for swelling, such as a cement matrix or a SIAL inorganic matrix.

The first option makes it easier to continue using the IDDS until the end of the operation of Krško NPP, and allows for the disposal of the existing and expected quantities of LILW without repackaging, while the second leads to greater stability of form in the contents of the FP and disposed LILW, but requires the introduction of new technology and facilities for additional processing at Krško NPP.

5.2.6.2.2.2 ***LILW from Krško NPP decommissioning***

Extension of the operation of Krško NPP to 2043 and the envisaged scenario of immediate decommissioning will generate approximately 5,307 t of LILW with a total activity of 2.4 x 10^5 TBq; this will have to be disposed of in accordance with the acceptance criteria. This is the estimate for primary and secondary LILW, which also includes activated low- and intermediate-level radioactive components from the interior of the reactor (291 t) and parts of the reactor vessel (16 t). The estimate further takes into account the quantity of LILW that will be generated by the processing of old steam generators that have already been replaced (161 t). [28] The entire quantity of containers, encompassing the Slovenian and Croatian portions of LILW for disposal from Krško NPP decommissioning, amounts to 661 N2 containers, while the design quantity of containers, which includes only the Slovenian half of LILW from Krško NPP decommissioning, amounts to 330 N2 containers. [6]

5.2.6.2.3 Institutional waste

5.2.6.2.3.1 LILW from the CSRAO

LILW is generated by small generators active in various fields of industry, medicine and science. This waste is stored at the CSRAO at Brinje prior to disposal. The waste is packed into drums, into its original protective packaging (sealed sources) or as special waste (this category includes bulk waste of larger dimensions or irregular shape). At the end of 2016, 832 packages of LILW (total volume 92.9 m^3, total activity 2.8 TBq) were being stored at the CSRAO, meaning that the storage facility was approximately 80% full. Given the current storage arrangements, the administrative storage capacity is 115 m^3 of RW, which includes 107.5 m^3 of ordinary storage capacity and 7.5 m^3 of capacity for special consignments. [9], [37]

Based on past experience, the annual intake of RW into the CSRAO is expected to be between 2 and 3 m^3 or less in the coming years, given that ARAO has already taken most of the historical waste. [9]

The total estimated quantity of stored waste at the CSRAO is 224 m^3 with a total activity of 8.29 TBq (if the storage facility operates until 2050). [30] This estimate also includes the 2 m^3 of RW that is expected to be generated by the decommissioning of the CSRAO. [9], [38] According to Chapter 4.4 of ReNPRRO16–25 and the acceptance criteria, [50] it will be possible to dispose of all LILW from the CSRAO at the LILW repository. The design quantity of the containers for the disposal of LILW that are stored at the CSRAO at Brinje and the waste from that facility's decommissioning amounts to 76.5 N2 containers. [6]

5.2.6.2.3.2 LILW from the decommissioning of the TRIGA reactor

Based on experiences from the decommissioning of TRIGA research reactors with a similar history of operation, and assuming that all waste generated during decommissioning will be radioactive, the estimated quantity of LILW generated is 227.5 t, or approximately 50 m^3 of unpackaged LILW with a total activity of 5.13 TBq, [30], [9] making a total of 40.5 N2 disposal containers. [6]

5.2.6.2.4 LILW from the operation and decommissioning of the repository and from the operation and decommissioning of the facility for the conditioning of LILW at Krško NPP

The waste that will be produced by conditioning at Krško NPP for disposal at the repository and by the operation of the repository itself is estimated to amount to 16 m^3 with a total activity of 1.1 GBq, where it is assumed that half of this waste will be produced at Krško NPP, where the process of conditioning for disposal is to be carried out, and half from the operation of the repository. [30]

The quantity of unpackaged LILW to be generated by the decommissioning of the LILW repository and of facilities at Krško NPP for the conditioning of LILW for disposal at the repository is estimated to be approximately 31 t with a total activity of 0.1 TBq. [30] The design disposal quantity of containers for the disposal of LILW from the operation and decommissioning of the repository and from the operation and decommissioning of the facility for the conditioning of LILW at Krško NPP totals 10 N2 containers. [6]

Table 5.1: Waste generated at LILW repository

LILW from operation of repository and from conditioning for disposal	Mass [tonnes]
Compressible	2
Non-compressible	14.1
Total	16.1
LILW from decommissioning of repository and from decommissioning of facilities at Krško NPP for conditioning of LILW	Mass [tonnes]
Contaminated components	17
Contaminated concrete	8.7
Combustible	1.4
Non-combustible	4.2
Total	31.3

5.2.6.2.5 Estimated total quantity of waste for disposal and estimated disposal volume by disposal phase

The capacity of the repository is sufficient for the disposal of half of the LILW that will be generated during Krško NPP operation up to 2043 and the subsequent decommissioning of Krško NPP (Table 5.2), and for the disposal of LILW from other Slovenian generators. The LILW requiring disposal will be placed in 990 disposal containers (design quantity of containers). One disposal silo will have to be built for disposal of the design quantities.

Table 5.2: Expected total quantities of LILW by source of generation [6], [28]

Source	**Quantity**	**Number of N2 disposal containers**		
		Total quantity of LILW	**Design quantity of LILW**	**Disposal volume**[1]
LILW from Krško NPP				
operation	3,612 m^3	1,067	533	6545.2 m^3
decommissioning and other LILW	4,665 t	661	330	5042.4 m^3
LILW from small generators				
CSRAO	224 m^3	76.5	76.5	939.42 m^3
decommissioning of TRIGA	228 t	40.5	40.5	497.34 m^3
Conditioning of waste for disposal, and operation and decommissioning of repository	47.4 t	18	10	122.8 m^3
Total		**1,862**	**990**	**12,157.2 m^3**

[1] A gross disposal volume of 12.28 m^3 per N2d container is assumed.

In order to estimate the quantities of LILW disposed of, it is assumed that waste generated up to the end of 2024, which is when the repository moves to the standby phase, will be disposed of during the first phase of operation of the repository (2022 to 2024). Therefore, 461 containers, or 71% of all operating LILW from Krško NPP, will have been disposed of at the repository by the end of 2024. Other operating waste and all waste from the decommissioning of Krško NPP will be disposed of between 2050 and 2061 after operations at the repository are recommenced in 2050. For institutional waste from the CSRAO and TRIGA the ratio is assumed to be the same as that applying to operational waste from Krško NPP, while for waste from conditioning for disposal the same assumption is made as for waste from the decommissioning of Krško NPP.

5.2.7 DEFENCE-IN-DEPTH

The defence-in-depth principle is taken into account at the LILW repository in design and management, with the aim of limiting radioactive releases.

Under the graded approach, the defence-in-depth principle is taken into account to the greatest possible extent in the choice of disposal concept itself and in the operation of the LILW repository. The disposal concept is based on a multi-barrier system, where multiple SSCs perform a single function, and multiple safety functions are deployed to achieve safety. The multiple barrier approach reduces the probability of undesirable and unforeseen events. The safety functions performed by individual SSCs are presented in Section 5.2.8

Under the categorisation and safety classification, which is provided in Section 5.3.10, it can be seen that safety functions are performed by multiple SSCs in parallel. The number of individual SSCs performing an individual safety function for the disposal silo is presented below.

P (physical containment)	4 SSCs
C (chemical containment)	4 SSCs
H (hydrological type)	7 SSCs
I (intrusion)	5 SSCs
S (structural stability)	4 SSCs
Sh (shielding)	3 SSCs
Su (support function)	10 SSCs
Se (security)	8 SSCs

Each SSC is designed to meet a basic safety function. The combination of safety functions was examined within the framework of the safety analysis (Section 7), while their testing, maintenance and operation is covered in Sections 6 and 8. As part of the safety analysis, the possibility of a failure in the safety functions of individual SSCs (engineered barriers) was also examined under the scenario of the early failure of engineered barriers.

Defence in depth is thus defined primarily by the multiple barrier approach, and the duplication of safety functions provided by multiple SSCs.

The function of physical containment of radionuclides disposed of in the LILW repository is performed by the following SSCs:

- the final package into which all wastes are loaded,
- the backfill in the package,

- the disposal silo, and
- the barrier between the silo and the aquifer.

In the event of the failure of an SSC or behaviour that deviates from its envisaged behaviour, the function of radionuclide containment is taken over by another SSC. The takeover of functions was addressed as a marginal state in the safety analysis (Section 7 of this draft safety analysis report), where the scenario of the early failure of engineered barriers, which envisages the total failure of all engineered barriers, is discussed.

The function of physical containment of radionuclides could be taken over indirectly by the function of shielding from radiation coming from radioactive waste. It is envisaged that the majority of waste will be packed in drums (packages), which in turn will be packed in the final package. The voids created after the disposal of the FPs will be filled with backfill material. All these elements and SSCs perform a shielding function.

The plan for the LILW repository uses concrete for its construction. Concrete is used in the repository not only because of its structural properties, but also because of its chemical properties, i.e. high pH. This affects the migration properties of the majority of radionuclides. In this environment the majority of radionuclides have high sorption coefficients in concrete, which means that the concrete binds them into its chemical structure, thereby preventing them from spreading into the environment. The clay barrier between the silo and the aquifer has similar properties.

One of the important passive safety elements at Vrbina LILW repository is the geological environment in which the repository is sited. This also reduces the impact of the disposed radioactive waste on people and on the environment. This is addressed in the safety analysis presented in Section 7 of this document.

5.2.8 SAFETY FUNCTIONS

5.2.8.1 Passive and active safety functions

Article 5 of the JV5 rulebook [1] stipulates that in designing a radiation or nuclear facility, the application of passive safety functions is desirable since it reduces the dependence on active safety functions, controls, and human intervention in ensuring safety.

The LILW repository is designed in such a way that it includes as many passive safety functions as possible, which helps to ensure the robustness of the facility. The safety functions are defined in the following section.

5.2.8.2 Basic safety functions

The safety functions and the requirements that stem from them are summarised below. They have been taken from the documents that form part of the process of drawing up the safety analysis. [39]

In accordance with point 67 of Article 2 of the JV5 rulebook, [1] a safety function is “a purpose that must be achieved or an action that must be performed in order to ensure radiation or nuclear safety”.

All safety functions are classified into five basic types with regard to long-term nuclear and radiation safety. These are:

P (physical containment): prevention of the migration of radionuclides by means of physical barriers,
C (chemical containment): prevention of the migration of radionuclides by means of chemical barriers and by using sorption and solubility limits,
H (hydrological): natural and man-made barriers that reduce the flow of groundwater through the repository,
I (intrusion): natural and man-made barriers that reduce the likelihood or impact of human intrusion into the repository,
S (structural stability): the use of primarily concrete barriers that ensure the structure/geometry of the repository.

Further safety functions are defined; these relate primarily to operational, nuclear and radiation safety. These are:

Sh (shielding): barriers that shield against radiation from radioactive waste,
Se (security): physical and technical security that prevents inadvertent access to waste and hostile acts in relation to radioactive waste,
Su (supporting): this is not a true safety function, but the SSCs that provide this function enable other SSCs that provide safety functions to perform those functions. Supporting functions also include procedures and instructions compiled for the operation of SSCs.

The safety functions that specific SSCs have to perform are defined in Section 5.3.10, which also classifies safety functions important to nuclear and radiation safety into passive and active functions.

5.2.9 DETERMINISTIC APPROACH TO DESIGN

The design of the repository has at all times made use of a conservative deterministic approach, mostly supported by calculations and analysis of safety-related design parameters and processes at the facility that arise after postulated initiating events. By means of judgments, analysis and calculations, it has been verified and confirmed that the permitted values of the basic safety parameters have not been exceeded, and that adequate safety limits have been provided.

The approach to the application of the criteria for achieving the right design solutions and safety limits was dependent on the type of design activity, and primarily consisted of the following in terms of individual types:

1. the use of standard analysis and calculation (e.g. in accordance with the Eurocodes) with safety limits in the forms of standardised safety factors,
2. the use of established engineering analysis (e.g. hydraulic, radiation) with the consideration of conservative input data and with the guidance of design towards solutions that ensure a safety limit (e.g. increasing the diameter of the flow element, extra wall thickness), and
3. the introduction of established design solutions on the basis of engineering judgments, where the compliance and the safety margin for the envisaged design events and states are known from reference facilities.

5.2.10 SINGLE FAILURE PRINCIPLE

Under the graded approach, the single failure principle was taken into account in design in the sense of the maintenance of safety functions in the event of failure. The basic safety functions presented in Section 5.2.8 represent the set of all safety functions that the LILW repository has, with regard to international best practice. The SSCs are designed to meet multiple basic safety functions simultaneously. The individual operational safety functions are presented in Section 5.3.10 of this draft safety analysis report. The majority of operational safety functions are passive, and in the event of the failure of one SSC will cover for one another whereby the operational safety function of the first is taken over by another SSC. This approach also contributes to the safe closure of the repository.

5.2.11 OTHER SAFETY REQUIREMENTS AND PRINCIPLES

This section presents the requirements for the basic technical properties of the repository relating to the planned facilities and all phases of the repository's lifecycle. The requirements are given for the type of repository, its capacity, and its construction, operation and closure.

The requirements set out in this section are the requirements that appear in national strategic and investment documents, and they refer to international guidelines that are generally applicable to LILW repositories regardless of the disposal concept chosen, or else are general requirements for the phases of the repository's lifecycle and the planned facilities that have been developed in tandem with the development and optimisation of the repository construction design and changes to the legislation, and are taken from the design bases for the draft safety analysis report. [2]

5.2.11.1 Purpose of construction of repository (required operational capacity and requirements)

I. Radiation and nuclear safety regulatory requirements

1) The purpose of the construction of the repository and the required operational capacity and requirements are defined in ReNPRRO16–25: [9]

   The repository should be equipped with the technological systems and devices that are necessary, from the technical point of view, for the disposal of pre-conditioned disposal containers. All LILW for disposal should be conditioned at Krško NPP, which is also responsible for transporting containers that have been conditioned for disposal to the repository. Disposal containers are used to condition waste for disposal, as these provide for relatively easy transport and handling. The optimised design of the repository also enables expansion of the repository in terms of disposal capacity, as well as in terms of the capacity of technological systems and devices. The repository should be constructed gradually and in a modular fashion; this will enable it to be adapted to the required disposal capacities, allow it to recommence operation after the standby phase, and enable it to adapt to factors that could affect its construction, capacity and operation, such as new waste disposal methods and techniques, and improved estimates of the quantities of LILW to be generated by the decommissioning process.

The conditioning of all LILW at Krško NPP for disposal at the repository is allowed under Article 95 of the ZVISJV, [23] which permits the operator of a nuclear facility to store and process radioactive waste and spent fuel for the requirements of the provider of the compulsory national public utility service of radioactive waste management, provided that it obtains the relevant licence from the authority responsible for nuclear safety.

II. Spatial planning acts, opinions and design conditions

1) Article 5 of the Decree on the DPN [26] defines the specific purpose of the repository area:

- In the area covered by the detailed plan of national importance, a nuclear facility is to be constructed for the permanent disposal of low- and intermediate-level radioactive waste produced in Slovenia.
- The repository encompasses an entrance section, the disposal area, and vacant areas.

Article 7 of the aforementioned provides, *inter alia*, that:

- The repository should have a disposal capacity of 9,400 m^3 of waste produced in Slovenia.
- The waste should be disposed of in disposal containers, which are in turn placed in two disposal silos, each of which has a usable volume of 20,000 m^3 and a bottom standing at a depth of 50 to 60 m relative to the elevation of the embankment. The disposal silos are to be located west of the technological facility, along the southern boundary of the area covered by the detailed plan of national importance.
- A hall with maximum floor dimensions of 60 m × 41 m and a maximum height of 20 m is placed above each disposal silo prior to construction. After the silo is sealed, the hall is removed.

Article 38 sets out the permissible deviations in the functional, design and technical solutions defined in the decree, and in the number and size of the silos and the quantities of waste:

- The number and size of the silos may change if it is shown, after further research and planning, that this is necessary or expedient because of subsequent findings regarding the geological, geomechanical and hydrogeological properties of the microlocation, and other technological and technical requirements for radioactive waste disposal.
- Deviations are permitted from the data shown in the cartographic annexes and from the quantities defined in the decree as a result of more precise processing of the designs and of the results of the safety analysis.

2) SNSA, Recommendations and design conditions for the NSP, 1.B.15.

The required capacities of the repository should be clearly defined as input data in the safety analysis. In addition to the LILW inventory from the operation and decommissioning of Krško NPP, when planning the capacities of the repository and producing the safety analysis, due consideration should be given to the possibility of extending the lifetime of Krško NPP to 2043, constructing a new nuclear power plant and using the repository to dispose of waste from the central radioactive waste storage facility at Brinje, the TRIGA research reactor and other radioactive waste generated in Slovenia.

III. Investor's requirements

1) The development of disposal technology solutions [40] is a study that proposes reasoned alternatives to the default solutions in the preliminary design as an optimisation of solutions, whereby the investment is reduced as far as possible and operation of the repository is optimised to the maximum possible extent. The requirements pertaining to optimisation of the solution are as follows:

- the repository should be equipped only with those technological systems and devices that are necessary, from the technical point of view, for the disposal of preconditioned disposal containers,
- the LILW should not be conditioned for disposal at the LILW repository site,
- disposal containers should be used to condition waste for disposal, as these enable relatively easy transport and handling,
- the number of full-time employees at the repository should be as small as possible, and
- the optimised design of the repository should allow for expansion of the repository in terms of disposal capacity, and in terms of the capacity of technological systems and devices.

2) The Feasibility Study (Rev. C) [27] states that the capacity of the repository should be sufficient for the disposal of half of the LILW that will be generated during the operation and decommissioning of Krško NPP, and for the disposal of all LILW generated by other Slovenian generators. One disposal silo will have to be built for disposal of the design quantities.

3) According to the inventory report, [30] the envisaged design disposal capacity of the repository should be sufficient for 12,000 t of unconditioned LILW.

5.2.11.2 Requirements regarding technological capacities and other repository characteristics

I. Radiation and nuclear safety regulatory requirements

1) According to Article 6 of the JV5 rulebook, [1] in designing a nuclear facility the application of passive safety functions is desirable since it reduces dependence on active safety functions, controls, and human intervention in ensuring safety.

The investor or operator of the repository should design the repository in such a way that the technical barriers are physically and chemically compatible with each other, with the disposed waste and with the properties of the site.

According to Annexes 3 and 5 of the JV5 rulebook, safety-related SSCs should be designed to withstand the impact of natural phenomena such as earthquakes, tornadoes, lightning or floods, or a combination thereof, and to prevent the mass collapse of building structures and the falling of heavy objects due to such collapse onto radioactive waste or safety-related SSCs. SSCs for the handling of packages should be designed with due regard to iodising radiation protection measures, the requirement for straightforward maintenance, and the need to minimise the likelihood and consequences of events and accidents. The repository should be provided with adequate equipment and packaging for the handling of damaged radioactive waste packages as soon as possible after the damage is detected.

The repository should be equipped with back-up storage capacities during emergencies, and provided with adequate ventilation systems that ensure the confinement of airborne radioactive particles during normal and abnormal events. Containment systems should be regularly monitored to the extent that allows the operator to judge when remedial measures to maintain safe storage are required.

3) Under the Decree on areas of restricted use of space resulting from a nuclear facility and the conditions of construction of facilities in these areas (UV3, Official Gazette of the RS, 36/04, 1003/06, 92/14), the centre of a nuclear facility must be located at a distance from existing and planned construction areas that corresponds to at least the distance that defines the smallest size of the wider area of controlled use as determined by the SNSA with regard to the highest design release of radioactive substances from the nuclear facility during the procedure for granting radiation and nuclear safety approval.

II. International standards, principles and directives

1) According to the IAEA Safety Standards Series (SSS), No. SSR-2/1, Specific Safety Requirements - Safety of Nuclear Power Plants: Design (2012), the requirements are that safety-related SSCs, including software for management and monitoring, should first be identified and then classified on the basis of their safety significance. Safety-related SSCs should be designed, constructed and maintained in such a way that their quality and reliability are commensurate with their classification.

III. Spatial planning acts, opinions and design conditions

1) Article 6 of the Decree on the DPN defines the specific purpose of individual parts of the repository.

Two disposal facilities (two underground silos with an access shaft and inspection corridors) are to be located in the area for the disposal of waste. The silo also consists of a hall and accompanying handling areas. Part of the waste disposal area is to be set aside for expansion of the repository's disposal capacities.

Article 7 of the decree provides, *inter alia*, that:

- Facilities in the entrance section, the administrative and service part of the repository and the area for the processing and conditioning of waste for disposal should be dimensioned and sited with the technical construction requirements and the capacities of the repository in mind, and planned as independent buildings or as groups of one or more facilities.
- Disposal and other facilities may be sited in areas set aside for the construction of facilities. The construction boundary beyond which disposal facilities may not be sited is shown in the graphical section of the detailed plan of national importance.
- A transparent fence should be erected around the perimeter of the repository site. The waste disposal area and the facilities for the processing and conditioning of waste for disposal should be secured by an additional fence. The height and exact location of the fences should be defined in the physical security plan for the repository.

The above requirements from the Decree on the DPN need to be taken into account in accordance with other requirements and with the development of the project, which envisages the construction of one disposal silo under the basic scenario and two disposal silos in the case of the expanded scenario (i.e. on condition that agreement is reached with Croatia on joint disposal).

2) SNSA, Recommendations and design conditions for the NSP, 1.B.15.

In future analysis, the current inventory of all LILW in Slovenia will have to be used and greater attention placed on the levels of radionuclides that most contribute in relative terms to the radiation load on the environment.

5.2.11.3 Requirements regarding phased construction and operation of the repository

I. Radiation and nuclear safety regulatory requirements

1) In ReNPRRO16–25 [9] (Strategy 4), timetables for operation, the standby phase, decommissioning, closure, and long-term controls and maintenance are proposed for the basic and expanded repository scenarios.

2) Under Article 4 of the JV5 rulebook, [1] an investor that intends to construct a radiation or nuclear facility, or an operator that intends to decommission such a facility should ensure in the design bases that the safety provisions from the safety report are adhered to, with due regard to all phases of the facility's lifecycle: design, construction, trial operation, operation, termination of operation, the standby phase, decommissioning and closure. In the case of the long-term control of repositories, these steps must be taken by the entity responsible for long-term controls. In the case of a repository, the standby phase is an intermediate phase between the operation and closure or re-operation of a repository, and is intended for the purpose of optimising repository operations. During the standby phase, the repository should be in a safe state in which all safety functions are in place.

If construction, operation, decommissioning or closure are carried out simultaneously, the work should be performed in such a way that it does not have an adverse impact on operational and post-closure safety.

During construction and operation of the facility, the repository operator should collect information that could contribute to an understanding of the properties of the site and the response of the site to the presence of the repository.

II. International standards, principles and directives

1) In IAEA Technical Report Series No. 417: Considerations in the Development of Near Surface Repositories for Radioactive Waste (2003), Section 2.2 defines the phases of operation of a LILW repository:

- Pre-operational phase, which covers the selection of a disposal concept, the search for a site and the siting process and, above all, procedures for licensing the facility, leading to construction of the repository. This phase usually lasts between five and ten years, or sometimes longer.
- Operational phase, in which the repository is open and working/operational. RW packages that meet the acceptance criteria are received at the site and loaded into

disposal units. All auxiliary waste processing/conditioning facilities and systems are operating at the same time. At the end of the operational period, steps are taken to commence closure of the repository. This is followed by the decommissioning of facilities and systems, and the disposal of contaminated materials. The repository is usually sealed and closure caps installed. During the closure process, institutional controls are put in place; these may include active controls (such as monitoring, maintenance, remedial work) and passive controls (such as restriction of access to the repository or record-keeping on repository operation). This phase usually lasts between 30 and 50 years, or sometimes longer.

- The post-closure phase includes the implementation of a long-term control and maintenance plan in accordance with a decision issued by the authority responsible for nuclear and radiation safety. Access to the repository site is controlled in order to prevent human intrusion.

2) Due account must be taken of the recommendations from IAEA-TECDOC-1256: Technical considerations in the design of near surface disposal facilities for radioactive waste (2001) regarding construction of the repository; these relate chiefly to construction procedures and the selection of construction materials and backfilling materials (Section 3.4.1) and recommendations regarding repository operation (Section 3.4.2), specifically the processing and conditioning of RW, transportation, and the maintenance of the repository's active and ancillary systems. Waste may also be processed and conditioned for disposal at the location at which it is generated.

III. Spatial planning acts, opinions and design conditions

1) Chapter IX of the Decree on the DPN permits the phased implementation of spatial planning arrangements. The phases are functionally complete units, and may be carried out and put into use separately or simultaneously.

IV. Investor's requirements

1) In the Feasibility Study (Rev. C) [27], the repository operation solution assumed involves operation being interrupted after the available waste has been disposed of, and the repository being restarted during the Krško NPP decommissioning phase. The following operating periods are assumed under the baseline scenario:

- A repository design phase up to the acquisition of the nuclear facility construction permit (this began in 2010 and will be completed with the acquisition of the construction permit).
- A three-year repository construction phase following acquisition of the construction permit.
- A two-year trial operation phase, after which a permit to use will be obtained (this permit is the basis for the granting of the operating licence).
- A regular operation phase from the beginning of 2022 until 2024, when all LILW from Krško NPP and other Slovenian LILW that meets the acceptance criteria will be disposed of at the site. Transition to the standby phase in 2025. The repository will be restarted in 2050, and will operate for the entire decommissioning period until 2061.

- An standby phase in 2025, when the repository remains standby until resuming operation in 2050.
- A closure and decommissioning phase in 2061 and 2062 (decommissioning in 2061, closure in 2062).
- A phase of preparing the repository for long-term post-closure controls.
- A phase of active long-term controls, which will last from several decades to a maximum of 300 years after closure (duration to be determined on the basis of safety analysis).
- A phase of passive long-term controls, which will last a maximum of 500 years after closure (duration to be determined on the basis of safety analysis).
- A phase of unrestricted use of the repository site following the end of passive controls, when the area of the repository will move to unlimited use.

The length of the active long-term controls and passive long-term controls was then reviewed in the safety analysis project, [30] whose results are presented in VP7 and VP12. The active long-term controls and maintenance will last for the 50 years between 2066 and 2115, while passive long-term controls are envisaged for a maximum of 250 years after the end of the active long-term controls. [41]

2) During the standby phase of the repository, steps should be taken to ensure that individual functions are scaled down to the extent necessary to ensure safe standby operation until the next disposal phase. [5]

5.2.11.4 Requirements regarding closure and decommissioning (preparedness for decommissioning)

I. Radiation and nuclear safety regulatory requirements

1) Under the ZVISJV, [23] the decommissioning of facilities includes decontamination and facility dismantling procedures, and procedures for the dismantling and removal of radioactive waste and spent fuel from the facility, and closure of the repository, which follows final decommissioning and is the completion of all the measures that must be carried out to ensure the long-term safety of the repository. According to Article 61, the operator of a nuclear facility should have sufficient financial resources guaranteed until the completion of decommissioning for implementing the prescribed radiation or nuclear safety measures and for the long-term post-closure controls of the facility. The funds should be also sufficient to pay all the radioactive waste management costs that arise during decommissioning or decontamination.

2) Under ReNPRRO16-25, [9] a decision will be taken for the basic and expanded scenarios, depending on the analysis of the need for further disposal, as to whether the repository continues to operate beyond 2061, or is closed in 2062 and long-term controls and maintenance commenced.

3) Article 13 of the Joint Convention [42] provides that Slovenia, as a contracting party, shall, when selecting the site of proposed facilities, take the appropriate steps to ensure that procedures are established and implemented for a proposed radioactive waste management facility to evaluate all relevant site-related factors likely to affect the safety of such a facility during its operating lifetime as well as factors related to the facility after closure.

Article 14 of the Joint Convention [42] provides, *inter alia*, that appropriate steps should be taken to ensure that:

- at the design stage, conceptual plans and, as necessary, technical provisions for the decommissioning of a radioactive waste management facility that is not a repository are taken into account,
- at the design stage, technical provisions for the closure of the repository are prepared.

Article 16 on the operation of facilities refers to the requirement for Slovenia, as a contracting party, to take the appropriate steps to ensure that:

- decommissioning plans for the radioactive waste management facility are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body,
- plans for the closure of the repository are prepared and updated, as necessary, using information obtained during the operating lifetime of that facility, and are reviewed by the regulatory body.

4) Article 12 of the JV5 rulebook [1] defines the preparedness of a facility for decommissioning as follows:

- A radiation or nuclear facility should be designed so as to allow its decommissioning after the termination of its operation with minimum radiation loads on personnel and the public, and to avoid undue contamination of the environment in the course of decommissioning.
- The design of a radiation or nuclear facility should provide for the keeping of all detailed information on the facility required for its decommissioning that is generated in all the phases of the facility's lifecycle, including its siting, design, construction, trial operation, operation and termination of operation, and at the minimum, information on the use of the facility, events and accidents, the radionuclide inventory, dose rates and contamination levels.
- The information referred to in the previous paragraph should ensure proper incorporation of the design and modifications of a radiation or nuclear facility and its operational history into the facility-decommissioning programme.

Under Article 49 of the JV5 rulebook, in order to make the decommissioning process easier, the operator of a nuclear facility should maintain records in all phases of operation and decommissioning to ensure that all quantities of radioactive materials within the facility are known. Under Article 50 of the JV5 rulebook, the decommissioning programme should be based on safety analysis, an assessment of the radiological condition of the facility and the latest facility data. A graded approach should be used when the decommissioning programme is being drawn up in order to secure radiation and nuclear safety. The decommissioning strategy and the relevant plans should be adjusted to take account of the complexity of the facility, the type of radioactive waste within it, and phase of the facility's lifecycle in which the programme is being developed.

The decommissioning programme should be prepared, reviewed and updated in accordance with Articles 50 and 51 of the JV5 rulebook. [1]

Under the JV5 rulebook, the repository investor or operator should design the repository in such a way as to take account of any modifications or disruptions to the disposal system that could affect post-closure safety, and ensure that decommissioning generates the lowest possible quantities of radioactive waste at the lowest possible radioactivity.

II. International standards, principles and directives

1) In IAEA Safety Standards Series, No. SSR-5, [11] Requirement 19 provides that a repository should be closed in a way that ensures that the safety systems that have been identified as important to nuclear and radiation safety in the post-closure period are secure. Closure has to be considered in the initial design of the facility, which should be updated as the design output is developed. Before construction activities commence, there has to be sufficient evidence that, for example, the materials for backfilling and sealing and other materials will function in accordance with the design requirements. The repository has to be closed in accordance with the conditions set for closure as determined and approved by the authority responsible for nuclear safety in the repository's closure authorisation. The procedure of sealing voids with backfill and the placement of caps made of impermeable materials may be delayed for a certain period after the completion of the operation of the repository to allow, for example, for monitoring to assess the necessary aspects relating to safety after closure or for reasons relating to public acceptability.

2) The project designer should take account of the requirements given in IAEA General Safety Requirements Part 6, Decommissioning of Facilities (2014), which states that the decommissioning of facilities includes technical and regulatory procedures, together with the decontamination and removal of facilities or dismantling procedures, that enable subsequent procedures for closure of the repository to be carried out. In the event of the decommissioning of the repository, no provision has been made for the removal of facilities in which radioactive waste and spent fuel have been disposed of, such as disposal cells or units, the disposal silo, and disposal containers and canisters. The planning of the decommissioning of a facility should commence during the facility design phase, and should continue through all subsequent phases of the facility's lifecycle until the completion of decommissioning. At all phases of a facility's lifecycle, records and reports on the construction and operation of the facility, as well as all modifications made, should be stored and updated to aid the preparation of an appropriate decommissioning programme.

III. Recommendations and studies

1) Chapter 12 of PS 1.03 [5] provides that a repository should be closed in such a way that the prescribed dose limits for a member of the general public are never exceeded in the post-closure period. Evidence of this should be provided in the form of safety analysis in a way that is easily understandable.

5.2.11.5 Requirements regarding long-term controls of the repository

I. Radiation and nuclear safety regulatory requirements

1) Article 73 of the ZVISJV [23] provides that the plan of long-term controls for a repository should disclose:

   - the scope and content of the operational monitoring of radioactivity for the repository, the monitoring of natural phenomena that affect the long-term stability of the repository, and the functioning of individual parts of the repository,

– the criteria that form the basis for a decision to carry out maintenance work at the repository in response to the results of operational monitoring referred to in the previous indent or inspection activities.

2) Under Article 25 of the JV5 rulebook, [1] the investor should enclose with the application for approval of the construction of a radioactive waste or spent fuel repository a safety report on repository facilities for the period after closure, along with a plan of long-term controls for the repository, and financial guarantees for the payment of the costs of post-closure long-term controls. Under Article 43 of the JV5 rulebook, the safety report for a radiation or nuclear facility under construction, in trial operation or in operation, following termination of operation or undergoing decommissioning should contain a plan of long-term controls of the repository. Safety after the closure of the repository and the period of long-term controls should be planned and ensured using exclusively passive means.

The provider of long-term controls of the repository should ensure that the safety provisions from the safety report are adhered to during post-closure long-term controls and maintenance.

Under Article 56 of the JV5 rulebook, the provider of long-term controls at a closed repository should, for the storage of documentary material on nuclear facilities, set the periods of storage of that material in bylaws in accordance with the importance to radiation and nuclear safety, and should store it in suitable climatic conditions secure from theft, fire, water, biological, chemical, physical and other harmful impacts, ensuring that it is accessible for the full duration of the storage.

3) Article 26 of the JV10 rulebook [43] provides that the scope and duration of post-operational monitoring of radioactivity should be determined with regard to the expected environmental impact in the vicinity of the closed radiation or nuclear facility. The SNSA defines the implementation of post-operational monitoring of radioactivity in the approval of the application for a licence to terminate the operation of a radiation or nuclear facility.

4) Article 13 of the Joint Convention [42] provides that, when selecting the site of proposed facilities, each contracting party should take the appropriate steps to ensure that procedures are established and implemented for a proposed radioactive waste management facility to evaluate the safety factors likely to affect individuals, society and the environment, taking into account the possible development of conditions at the repository site after closure.

Under Article 15, each contracting party should take the appropriate steps to ensure that, before construction of a repository, a systematic safety assessment and an environmental assessment for the post-closure period is carried out, and the results evaluated against the criteria established by the regulatory authority.

Article 17 defines the post-closure institutional measures by which the repository operator ensures that, after closure of the repository:

records of the location, design and inventory of the facility required by the regulatory authority are preserved,

active or passive institutional controls, such as monitoring or access restrictions, are carried out, if required, and

if, during any period of active institutional controls, an unplanned release of radioactive materials into the environment is detected, intervention measures are implemented, if necessary.

II. International standards, principles and directives

1) In IAEA Safety Standards Series, No. SSR-5, [11] points 5.6, 5.7 and 5.8 of Requirement 22 provide that long-term safety may not be dependent on active controls alone, and that passive controls or systems, such as markers, record archives and safety fencing, should also be designed to reduce the risk of unauthorised access and external intrusion onto the site. The risk of intrusion should also be mitigated by the correct choice of site and facility design (point 5.10).

2) Section 4.1.2 of IAEA TECDOC-1572: Disposal Aspects of Low and Intermediate Level Decommissioning Waste [44] provides that post-closure institutional controls should consist of:

   - an active phase that includes monitoring and maintenance of the repository, accompanying facilities and, if needed, remedial actions, and
   - a passive phase that limits the use of activities and areas in the repository area.

   The duration of post-closure institutional controls can be expected to be a few hundred years at the most, with the exact period usually being a matter of the national radioactive waste management strategy. In the majority of countries, the period of control lasts from 50 years for very low level radioactive waste to up to 300 years for low and intermediate short-lived radioactive waste.

3) Section 2.2.3 of IAEA Technical Report Series No 417: Considerations in the Development of Near Surface Repositories for Radioactive Waste [45] provides that, during the period after the closure of the repository, any unexpected deviation in the operation of the disposal system revealed during the control and maintenance period should be adequately investigated, and appropriate remedial action taken. At the end of the post-closure institutional controls period, it is expected that the radioactivity in the waste will have decayed to acceptable levels and that the repository will no longer present a risk to people or the environment.

   The duration of the active and passive institutional controls should be determined on the basis of several factors:

   - properties of the waste,
   - properties of the site,
   - properties of the design of the facilities and systems, and
   - the requisite costs.

   Institutional control of a repository is usually required and effective for a few hundred years at the most.

4) The guidelines relating to LILW repositories contained in the IAEA Safety Standards for protecting people and the environment: Monitoring and Surveillance of Radioactive Waste Disposal Facilities, Specific Safety Guide No SSG-31 [46] should be observed. Long-term controls should include a plan for the transition from active to passive controls of the repository. The development and construction of the repository should also envisage when the conditions for the removal of active institutional controls and maintenance of the repository have been met, when long-term safety can be ensured by reliance on restrictions

on usage of the area, and when the reduction in the radiotoxicity of the waste means that the radiological risk under the scenario of inadvertent human intrusion is reasonably low.

III. Recommendations and studies

1) Chapter 12.1 of PS 1.03 [5] provides that, as per Article 43 of the JV5 rulebook, [1] a long-term control plan for the repository is a mandatory part of the safety report. A summary of the long-term control plan is given in this section. The duration must be defined for each individual period of long-term controls.

The long-term control plan regulates:

- active long-term controls of the repository, which cover monitoring of the state of the repository and any required remedial actions, and
- passive long-term controls, which encompass the method and forms of marking of the repository site, the storage and accessibility of basic documentation on the closure of the repository, and other information necessary for the implementation of the planned isolation measures based on the design.

The active controls should include at least the following:

- the scope and content of the monitoring of radioactivity for the repository, the monitoring of natural phenomena that affect the long-term stability of the repository, and the functioning of individual parts of the repository,
- an illustration of periodic inspections,
- a description of the necessary regular maintenance, cleaning and preventive work on systems that are to remain functional, measuring equipment, and other facilities and devices connected with monitoring and with the stability and integrity of the repository, and
- the criteria that form the basis for a decision to carry out maintenance work at the repository in response to the results of monitoring and surveillance activities.

The passive controls should include at least the following:

– a programme for the storage of records on the repository, and
– restrictions on the use of land at the repository site.

2) The US DOE’s Long-Term Stewardship Planning Guidance for Closure Sites [47] defines the content and sections of a long-term control plan. The plan should have clear objectives and define the scope and organisation of controls, and the powers and responsibilities of the control provider, provide a description of the planned controls of the repository, a land use plan, and a funding and staffing plan, and provide for the archiving of data, records and documents and for public participation.

3) Due account is taken of the guidelines in Section 3 of NUREG 1388: Environmental Monitoring of Low-Level Radioactive Waste Disposal Facility, [48] which defines the objective of long-term controls and maintenance as compliance with the conditions and restrictions applying to the closure of the repository so as to provide data and measurements to support the expected long-term evolution of the repository after closure and provide information for the public. Periodic physical surveillance and monitoring of the

radioactivity of the environment is proposed during the period of long-term controls and maintenance.

IV. Investor's requirements

The project designer should take account of the fact that active long-term controls are planned to commence at the beginning of 2066, when all preparatory activities have been performed for a transition to controls following the period of transition of the repository to long-term controls and maintenance (2063–2065) and after the control and maintenance provider has taken over the repository for long-term controls and maintenance. [41]

Active long-term controls and maintenance are expected to last 50 years (2066–2116), unless another duration is determined on the basis of safety analysis and operational experience. [41]

After active long-term controls and maintenance come to an end, the repository passes into the passive long-term controls phase, which is expected to last a maximum of 300 years after the closure of the repository (2117–2447), unless another duration is determined on the basis of safety analysis and operational experience. [41]

5.2.12 PROBABILISTIC DESIGN CRITERIA

Probabilistic safety rules were not applied in the designing of the LILW repository. In conceptual terms the repository is seen as a relatively simple nuclear facility, and probabilistic criteria were therefore not applied. Sensitivity analysis was conducted within the framework of the safety analysis, and helped in the optimisation of design solutions, and in the interpretation of the safety analysis. In line with the graded approach, probabilistic design criteria are not applied to the LILW repository, as the deterministic and probabilistic safety analysis conducted in accordance with Article 15 of the JV5 rulebook: [1]

- is based on substantiated conservative methods, assumptions and arguments,
- contains an assurance that uncertainties and their impact have been taken into account; this assurance is given in the form of conservative assumptions, having regard for safety factors, and uncertainty and sensitivity analysis,
- demonstrates that the design bases include sufficient safety margins to ensure coverage of all design-basis events,
- are verifiable and repeatable.

5.2.13 RADIATION PROTECTION

Radiation protection is addressed in detail in Sections 7 and 13 of this draft safety analysis report.

5.2.14 DEVIATIONS FROM REGULATIONS AND STANDARDS CITED IN SECTION 4.1

The SSCs planned and described in this draft safety analysis report fully comply with the requirements and standards. The SSCs are presented in detail in Section 6 of this draft safety analysis report.

5.3 SAFETY CLASSIFICATION AND CATEGORISATION OF SSCs

5.3.1 DEFINITION OF BASIS FOR IDENTIFYING SSCS

As required by Article 70a of the ZVISJV, [23] design bases should be drafted at all phases of the lifecycle of a nuclear facility, and particularly as part of the safety report.

The LILW repository project is currently at the stage of preparation of documentation for acquisition of a construction permit. One important step in this phase is the acquisition of environmental consent, which also includes a preliminary radiation and nuclear safety approval issued by the authority responsible for nuclear safety. A draft safety analysis report and the accompanying design bases within the framework of the environmental impact report were drawn up in order to acquire preliminary consent.

SSCs are identified and described in the design bases on the basis of the design documentation available at the time that the design bases were compiled. At this stage, the project itself develops and is upgraded very quickly. As part of the preparation of this draft safety analysis report and the design bases, in the phase of obtaining the environmental consent individual SSCs are identified and described in relation to the design solutions from the preliminary design, [31] and the documents that optimised the design solutions [40], [49] and [50] and Revision C of the conceptual design. [6]

In order to obtain a construction permit, a safety report and a new revision of the design bases including the design solutions identified in the construction permit project will have to be prepared.

5.3.2 DEFINITION OF STRUCTURES, SYSTEMS AND COMPONENTS

5.3.2.1 Definitions and introduction

As per the definition in the JV5 rulebook, [1] the abbreviation SSC:

> "... denotes a set of structures, systems and components. Structures are passive structures such as buildings and shields. A system comprises several components combined so as to perform a specific (active) function. SSCs include instrumentation and regulation software. In the case of a radioactive waste storage facility or repository, radioactive waste packages are also classed as SSCs."

The IAEA Glossary [51] also contains a definition, which reads as follows:

> "Structures, systems, components (SSCs). A general term encompassing all of the elements (items) of a facility or activity that contribute to protection and safety, except human factors. Structures are the passive elements: buildings, vessels, shielding, etc. A system comprises several components assembled in such a way as to perform a specific (active) function. A component is a discrete element of a system. Examples are wires, transistors, integrated circuits, motors, relays, solenoids, pipes, fittings, pumps, tanks and valves."

In accordance with the JV5 rulebook, safety-related SSCs should be designed to withstand the impact of natural phenomena such as earthquakes, tornadoes, lightning or floods, or a combination thereof, and to prevent the mass collapse of building structures and the falling of heavy objects due to such collapse onto radioactive waste, spent fuel or safety-related SSCs.

The SSCs for the planned radioactive waste repository at Vrbina, Krško are identified below in accordance with the design output, optimisation studies and safety analysis produced so far, [6], [31], [40], [50], [49], [19] and the requirements of the JV5 rulebook. [1] In this chapter, the SSCs are identified and described. They will be classified and categorised in relation to safety in the following chapters.

5.3.2.2 Identification of facilities

The purpose of this section is to identify, as per the conceptual design [6] and the safety analysis, the various facilities that will be constructed as part of the LILW repository, and to determine the activities to be performed within them and, if possible, the extent of their performance.

Table 5.3: Facilities at Vrbina LILW repository, and activities taking place at the facilities

Facility	Activities taking place at the facility
Disposal facility	Waste disposal
	Collection and monitoring of drainage water
	Environmental monitoring
	Operational monitoring (radioactivity and other parameters)
Technological facility	Operational management of the disposal facility
	Back-up power supply
	Control point (including changing facilities)
	Radiation protection
	Monitoring controls (measurement displays, etc.)
	Radioactive waste storage facility (for waste generated at the repository)
Administrative and service building	Boiler room
	Fire protection station
	Workshop
	Management of the repository
	Storage of classified documents, computer and communications systems
	Physical security management (security officer, camera surveillance, etc.)
Physical security facilities	Implementation of physical security of repository
External arrangements	Collection of rainwater runoff and drainage water
	Internal transport routes
Infrastructure lines and connections	Water supply
	Electricity supply
	Sewerage provision (rainwater runoff and faecal)
	Provision of telecommunications connections
	Provision of road connection
Monitoring facilities	Implementation of monitoring

5.3.2.3 Identification of SSCs

In order to take a more systematic approach to identifying the SSCs, the latter have been broken down by facility and device as defined in the conceptual design [6] and described in the previous chapter.

- disposal facility,
- technological facility,
- administrative and service building,
- physical security facilities,
- external arrangement facilities,
- infrastructure lines and connections,
- monitoring facilities.

The SSCs identified are listed in the Table 5.4 below.

Table 5.4: SSCs identified for LILW repository

SSC designation	Facility/device	SSC description	Remarks
O1	Disposal facility	Final package (FP)	Final package as defined by the acceptance criteria
O2	Disposal facility	Backfill	Material that will serve as backfill for voids between final packages and the wall of the silo
O3	Disposal facility	Silo	Silo as the disposal unit. From the lower part of the silo to the top (concrete slab to seal the silo) – secondary liner
O4	Disposal facility	Drainage system	System that allows any percolating water to be removed. It can be captured outside the silo or between the primary and secondary liners. It includes a drainage system with a device and system for collecting and pumping water
O5	Disposal facility	Barrier between silo and aquifer	Clay top as per the design
O6	Disposal facility	Backfill material from the upper height of the clay top to the surface	Natural-like materials to be placed in the area above the clay top and the surface to re-establish a primary state
O7	Disposal facility	Structure that enables a construction pit to be excavated	Building structure required for excavation – primary liner
O8	Disposal facility	Flood protection – embankment	

O9	Disposal facility	Hall above silo	
O10	Disposal facility	Disposal/transport equipment	Devices for the transport of final packages to the silo, and the transport of backfill and other material and, when required, workers
O11	Disposal facility	Electrical installations	Lighting, power, emergency lighting, diesel generator (back-up electricity supply)
O12	Disposal facility	Fire protection system	
O13	Disposal facility	Physical security systems	
O14	Disposal facility	Monitoring systems	
O15	Disposal facility	Mechanical installations	Ventilation
O16	Disposal facility	Radiation protection system	
O17	Disposal facility	Telecommunications	Telephony, antenna systems, computer connections and equipment, voice communication devices and public address system, etc.
T1	Technological facility	Building / building structure	
T2	Technological facility	Flood protection – embankment	
T3	Technological facility	Electrical installations	Lighting, power, emergency lighting, diesel generator (back-up electricity supply)
T4	Technological facility	Mechanical installations	Ventilation, water supply, heating/cooling, technological connections (water, gases)
T5	Technological facility	Sewerage systems	Vertical and horizontal sewerage
T6	Technological facility	Physical security systems	
T7	Technological facility	Radiation protection system	Control entry and exit points (personnel, equipment, material)
T8	Technological facility	Telecommunications systems	Telephony, antenna systems, computer connections and equipment, voice communication devices and public address system, etc.
T9	Technological facility	Fire protection system	
T10	Technological facility	Monitoring	Operational and environmental monitoring within the technological facility

US1	Administrative and service building	Building / building structure	
US2	Administrative and service building	Flood protection	
US3	Administrative and service building	Electrical installations	Including back-up electricity supply
US4	Administrative and service building	Mechanical installations	Ventilation, water supply, heating/cooling, technological connections (water, gases), firefighting system
US5	Administrative and service building	Sewerage system	Vertical and horizontal sewerage
US6	Administrative and service building	Physical security systems	
US7	Administrative and service building	Telecommunications systems	Telephony, antenna systems, computer connections and equipment, voice communication devices and public address system, etc.
US8	Administrative and service building	Fire protection systems	
F1	Physical security facilities	Outer perimeter fence	
F2	Physical security facilities	Inner perimeter fence	
F3	Physical security facilities	Other physical security systems	
Z1	External arrangements	Embankment	Embankment provides flood protection
Z2	External arrangements	Transport-related arrangements	
Z3	External arrangements	Planted areas	
Z4	External arrangements	Exterior lighting	
Z5	External arrangements	Collection and drainage of rainwater runoff and waste water	Also includes control pool (preliminary design)
Z6	External arrangements	External connection to the water supply system and hydrant network	

I1	Infrastructure lines and connections	Electricity	
I2	Infrastructure lines and connections	Telecommunications	
I3	Infrastructure lines and connections	Water supply system	
I4	Infrastructure lines and connections	Faecal sewage system	
I5	Infrastructure lines and connections	Rainwater runoff system	
I6	Infrastructure lines and connections	Road connection	
M1	Monitoring facilities	Monitoring	Several types of operational monitoring (environmental, radiological, etc.) will be carried out during the operation of the repository

5.3.3 SSC DESCRIPTION: DISPOSAL FACILITY

Section 5.3.3 of the draft safety analysis report consists of the design bases and a description of the SSCs (disposal components), which are understood as requirements that the planned repository needs to meet. The use of materials to meet the requirements is then defined in other sections of the draft safety analysis report, most notably Section 6, which describes the individual SSCs. The LILW repository is in the planning phase (obtaining environmental consent), and so the materials for individual SSCs have not been precisely and finally defined. The properties that the materials will have to comply with are defined. Later phases of the safety report will also include evidence that the appropriate materials have been used.

5.3.3.1 O1 – Final package

A final package (FP) for the disposal of LILW at the repository is a container of the appropriate dimensions conditioned to meet the acceptance criteria. Waste is placed in an FP according to individual waste streams and the form of the waste. Voids between loaded wastes are filled as appropriate with backfill mortar. The FP is equipped as required for transport purposes.

Under conceptual design Rev. C, [6] an N2b container with reinforced concrete walls, cover and base is used for LILW disposal. SSCs are designed so that the safety assessment provides for and takes account of the reliability (achievement of the prescribed parameters) of the container over a specific period, after which the process of degradation begins.

The basic geometry of a container is determined on the basis of the placement of four TTCs (with the internal corners reinforced). The geometrical details of the container are given in the table below.

Table 5.5: Geometrical characteristics of N2b container [6]

Parameter	Unit	Value
Geometrical data on container		
External dimensions		
Width	m	1.95
Length	m	1.95
Height	m	3.30
Bevelled external edges of the walls (in both directions)	m	0.20
Internal dimensions: base of container		
Width	m	1.49
Length	m	1.49
Internal dimensions: top of container		
Width	m	1.55
Length	m	1.55
Height (prior to attachment of cover)	m	3.07
Height (after attachment of cover)	m	2.87
Thickness of lower plate	cm	23
Thickness of wall at top	cm	20
Thickness of wall at base	cm	23
Geometric data on cover – maximum dimensions		
Width	m	1.66
Length	m	1.66
Width of support	cm	5.5
Thickness of cover	cm	20
Thickness of cover above supports	cm	20
Volume of container		
Gross volume (external occupation of space)	m^3	12.28
Net volume (after attachment of lid)	m^3	6.31
Weight		
Cover	t	1.36
Empty container with cover	t	14.92
Maximum permitted weight of full container	t	40

As one of the most important engineering elements of a multi-barrier system for preventing the release of radioactive substances from the repository into the environment, as the final package a concrete container must function as:

- a biological shield before disposal,
- mechanical protection for the LILW during storage and disposal,
- a basic safety element during transit and internal transport (repositioning) of LILW in the container,

- a basic layout criterion in the process of conditioning waste for disposal, and
- the primary object of LILW management in the area of the disposal silo.

The basic characteristics of the N2b container are:

- the container is lifted from below – a steel construction with wheels is lowered from the top to the bottom of the container and grips it, and the rotating legs turn around and fit into grooves designed for that purpose on the bottom of the container,
- lifting from the bottom provides for a safer and more controlled container lifting and release process,
- the proposed lifting technique avoids the possibility of tensile stress in the concrete when the container is being moved (lifting and release),
- the required distance between the containers when this lifting technique is being used is approximately 20 cm (due to the protruding steel construction of the gripper and the rotating lifting legs),
- the external corners of the containers have a 20 cm bevel.

The container is constructed in such a way that all possible impacts and combinations of impacts are borne by the reinforced concrete structure without additional built-in steel elements; similarly, there will be no steel elements or reinforcement on the external surfaces of the container.

The proposed container is designed, under transport regulations, as an IP-2 or Type A container.

A prototype disposal container was produced for the purposes of determining the properties and safety functions. The prototype was produced on the basis of findings in previous project phases in the development of the container, having regard for the findings from the development of the prototype. The compliance of the prototype disposal containers with the regulatory and design requirements is established via a testing programme. The programme was drawn up as a component of the documentation for issuing Slovenian technical approval for the container prototype.

The reinforced concrete disposal container addressed by the technical approval consists of the following elements:

- reinforced concrete container without cover,
- reinforced concrete cover,
- anchor elements and screws that serve to fix the cover to the container,
- backfill mortar and grout.

The following conclusions were established on the basis of the testing programme prescribed for the container.

Tests of the basic materials (cement, aggregate, mineral admixtures) disclose values that are in compliance with the declared properties of the certified basic materials used.

Investigations of the fresh concrete show it to have attained a suitable pouring quality (self-compacting concrete) for the pouring process used, i.e. contractor pouring, and for the designed level of reinforcement of the container.

Tests of the solidified concrete show that the values given in container testing programme no. 10/17 [52] were achieved. When poured well, and with the proper care, the concrete is of a quality that guarantees that a container made from it will meet all functionality and durability requirements.

Investigations of the fresh backfill mortar show it to have attained a suitable pouring quality for the projected method of pouring (contractor).

Investigations of the solidified backfill mortar show that the criteria given in container testing programme no. 10/17 [52] were met in full.

The backfill mortar demonstrates all of the required properties in connection with its method of pouring and envisaged function.

Investigations of the fresh grout show it to have attained a suitable pouring quality for the envisaged method of pouring.

Investigations of the solidified grout show it to meet the criteria given in container testing programme no. 10/17 [52] in full.

The grout demonstrates all of the required properties in connection with its construction use and envisaged function.

The research established that the prototype container satisfies the water permeability requirements, as its permeability is a class lower than the requirement. The tests also established that the materials used ensure gas permeability.

On the basis of the container drop tests it can be concluded that the container complies with the ADR requirements and is suitable for the transport of dangerous goods by public roads. In all the tests it was established that the radiological protection did not decline by more than 20% after a container drop, as limited by the given requirements. All the other requirements [5] applying to an IP-2 package were also satisfied.

It was established that the proposed lifting solution is suitable, and that the lift grips have been suitably designed for the needs of handling the disposal container.

Testing of the insertion of packages established that the approach to the placement and fixing of drums in the container is suitable, as all voids were properly filled.

Two types of investigation were conducted on the produced container:

- investigation of the materials (concrete) in the container and materials removed from the container, and
- investigation of the container itself.

The investigations of the materials (concrete) in the container and the materials removed from the container prove that the inbuilt materials achieve properties comparable to those measured in samples from concrete containers, and that during pouring and after care there were no adverse impacts on the quality of the materials.

Investigations of the container itself (water permeability, drop test) prove that a container produced in accordance with the design documentation and from materials that meet the requirements cited in the container testing programme (10/17) satisfy all the required functions with regard to mechanical robustness, stability, durability and isolation capability (P: physical containment; C: chemical containment; H: hydrological; I: intrusion; S: structural stability) in all phases of use (during storage, during transportation and internal repositioning, during conditioning and during disposal).

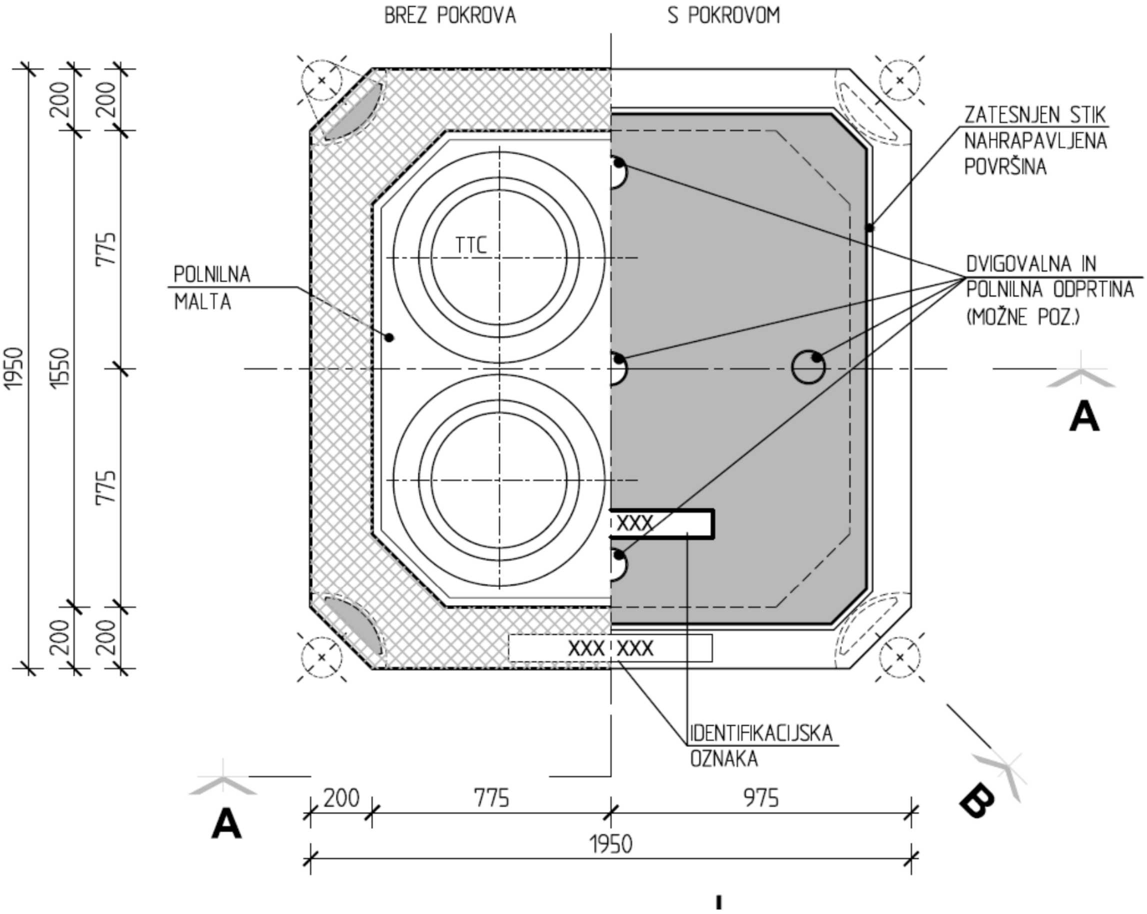


Figure 5.1: Ground plan of container – FP [6]

BREZ POKROVA	WITHOUT COVER
S POKROVOM	WITH COVER
ZATESNJEN STIK NAHRAPAVLJENA POVRŠINA	SEALED INTERFACE UNEVEN (RUGGED) AREA
DVIGOVALNA IN POLNILNA ODPRTINA (MOŽNE POZ.)	LIFTING AND FILLING OPENING (POSSIBLE POSITIONS)
POLNILNA MALTA	GROUT
IDENTIFIKACIJSKA OZNAKA	ID CODE

Every container must be furnished with an identification code.

Each concrete container will contain either four TTCs, 12 200-litre containers, an appropriate combination of TTCs (Type T1 or T2) and 200-litre containers, four 320-litre containers in combination with 200-litre containers or TTCs, or LILW in unpackaged (bulk) form (useable/net volume of 6.31 m^3).

The durability and degradation of the final package is described in more detail in Section 6.2.1.1.1 of this draft safety analysis report.

5.3.3.2 O2 – Backfill

This is a suitable material (concrete) used to fill the voids that appear during the disposal of FPs, between the walls of the silo and FPs and between FPs themselves. A gap of 20 cm is envisaged between FPs. A levelling concrete layer with a thickness of up to 20 cm is envisaged on every two layers of waste, but only if necessary.

5.3.3.3 O3 – Silo

The silo is the disposal unit, and a facility at an LILW repository. It is drum-shaped, and is excavated into a low-permeability stratum. FPs are disposed of in the silo, and the voids are filled with backfill.

The conceptual design [6] envisaged the construction of one silo on the far south-eastern part of the repository site. The site also enables the repository to be expanded with the construction of additional silos, if the need arises.

The embankment plateau on which the silo is to be constructed is located at an elevation of 155.2 m above sea level. The safety parapet of the silo is located 1.3 m higher and constitutes a safety barrier and additional protection against probable maximum flood (PMF).

The silo is designed as a cylindrical, reinforced concrete structure with a clearance diameter of 27.3 m and a height (depth) of 55 m. Inside the silo is a vertical communication shaft containing stairs, a lift, and two shafts for installation lines and the transporting of equipment.

The net floor area of the silo allows the arrangement of 99 containers at each level. The height of the facility is designed in such a way that ten container levels, plus the planned sealing layer (reinforced concrete slab, clay), are located below the level of the existing aquifer. Temporary exits to the interior of the silo are planned along the height of the vertical communication shaft; these will facilitate access to working levels when the repository is being filled. As the filling of the silo progresses, these exits will gradually be put out of use and filled with concrete.

The silo will be excavated after the necessary preliminary primary geotechnical measures have been carried out. A preliminary thick-walled reinforced concrete diaphragm is planned along the entire depth of the silo excavation in order to secure the excavation work. During the excavation work itself, special attention should be given to the possibility of the hydraulic fracturing of the bottom during construction. The planned thickness of the primary liner is 1.2 m. A reinforced concrete structure (floor vault) is placed on the invert of the silo. The bottom of the silo will be of solid concrete construction containing a permanent drainage basin for the collection of any percolating water during silo operation. The drainage basin will be accessible via the vertical communication shaft.

PEHD will be placed between the primary and secondary liners; this will provide additional hydro insulation. The secondary liner is planned to a thickness of 1 m and will be locally thickened in the lower part to provide protection against the flooding of the silo when full hydrostatic pressure occurs (buoyancy forces).

After the silo has been filled with FPs, the levelling of the upper part of the silo is planned, along with the construction of a 120-cm-thick reinforced concrete slab.

All dimensions of the structural elements are taken from Revision C of the conceptual design [6] and are part of the project and design dimensioning of individual structural elements.

Figure 5.2: Schematic illustration of disposal silo prior to start of filling [6]

Etaža	Floor
Sekundarni AB obloga (C30/37)	Secondary RC liner (C30/37)
Sekundarni AB obloga (C35/45)	Secondary RC liner (C35/45)
Primarna zaščita	Primary protection
Vzdolžni prerez (Pred polnjenjem) 1: 200	Longitudinal section (prior to filling) 1: 200

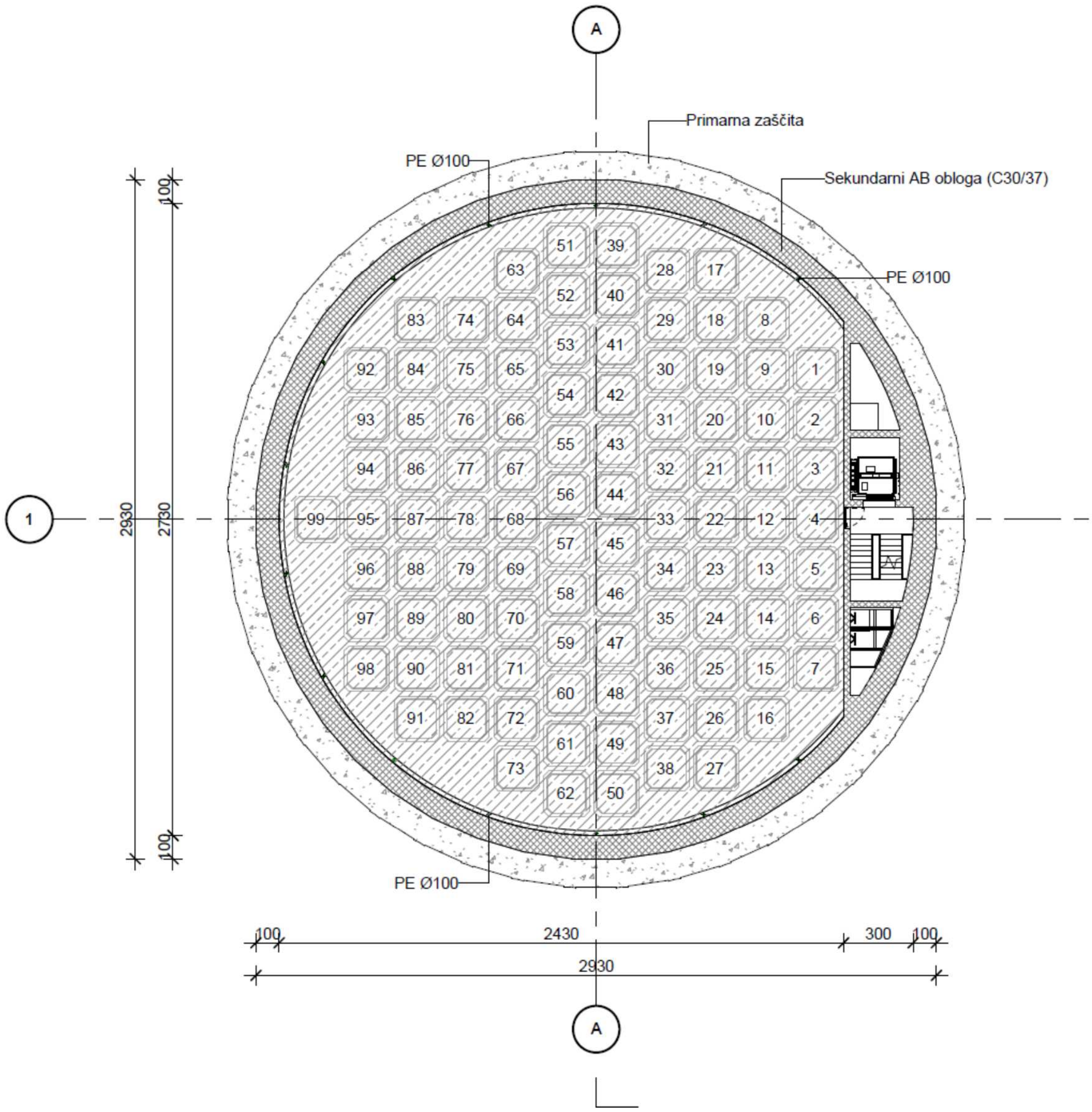
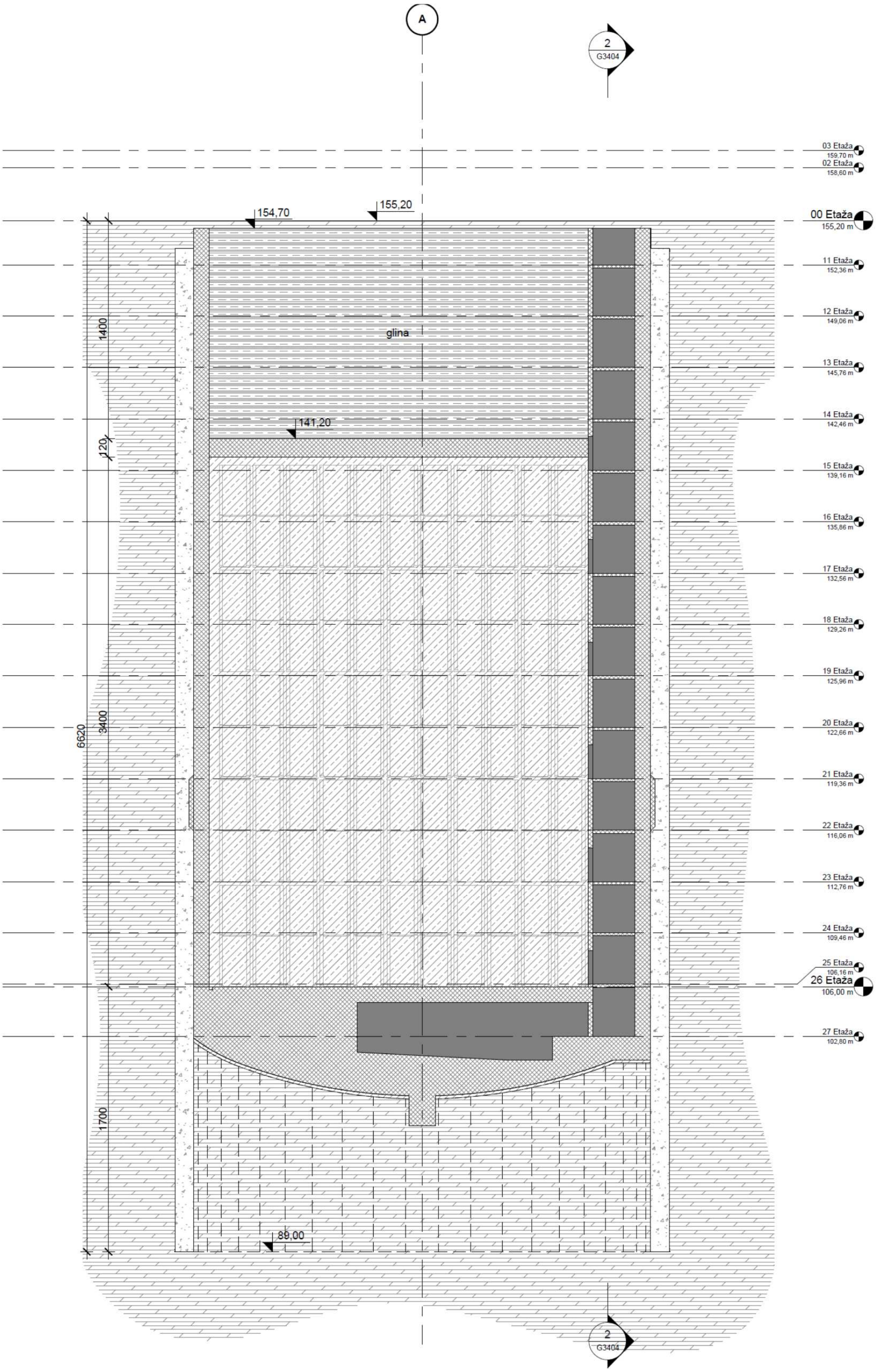


Figure 5.3: Filling of silo: first level [6]

Primarna zaščita	Primary protection
Sekundarni AB obloga (C30/37)	Secondary RC liner (C30/37)
PE Ø100	PE Ø100



1 **Vzdolžni prerez (Končno stanje)**
1 : 200

Figure 5.4: Silo sealing concept following end of operation [6]

Etaža	Floor
Vzdolžni prerez (Končno stanje) 1: 200	Longitudinal section (final position) 1: 200

5.3.3.4 O4 – Drainage system

The drainage system ensures that any water that percolates into the disposal silo or from the surroundings is removed. It comprises a system for collecting percolating water, a system for sampling and carrying out quality controls on the sampled water, and a transport system to SSC Z5 (collection and drainage of rainwater runoff) or to the point where potentially contaminated water can be safely transported for processing.

The drainage system on the bottom of the silo comprises a series of radially installed PEHD DN 200 drainage pipes that meet in the central part, i.e. at the lowest point of the base platform of the silo. The drainage system's collection pipes lead to the pumping basin. Drainage pipes will also be laid vertically on the edge of the silo. These will be installed as the silo is filled and will also be connected to the drainage system on the bottom of the silo.

The water collected in the collection tank will be radiologically inspected and then, depending on the results of the measurements, conveyed via the collection tank (Z5) to the sewerage network (treatment plant) or, if there is contamination, treated on site or sent elsewhere for treatment.

After operation of the silo comes to an end and when it is being sealed, the drainage system will also be sealed.

Voids between the disposed containers will be filled with backfill concrete (NSR SSC O2). Data about the backfill concrete is given in construction plan 3/6: silo (report NRVB---5G1401), and is as follows:

Table 5.6: Data on backfill concrete

Parameter	Value/description
Fresh concrete parameters	Self-compacting concrete
Cement	CEM III/B 32,5 LH/SR (SIST EN 197-1)
Aggregate	D_{max} = 16 mm (option 22 mm)
Degree of compactability SIST EN 12350-8:2010	Target value 700 mm (± 50 mm)
Viscosity EN 12350-8:2010	$t_{500} \geq 2.0$ s
Viscosity EN 12350-9:2010	VF 1 < 9.0 s
Passing ability ratio EN 12350-10:2010, modified L-box, no reinforcement	PL > 0.9
Resistance to segregation EN 12350-11:2010	SR ≤ 15%
Strength class	C25/30
Shrinkage	0.5 mm/m @ 180 days

The voids in the container will be filled with backfill mortar, which is a component of the container (FP, SR SSC O1). A description of the backfill mortar is given in the documentation that forms the basis of the granting of the technical approval for the container.

The voids in the drainage system will be backfilled with the same or a similar material as the backfill for the voids between containers.

The backfill material envisaged in the design has also been taken into account in the safety analysis.

5.3.3.5 O5 – Barrier between silo and aquifer

This SSC shields the disposal unit (the silo) from the impact of the water table, which is located in the Quaternary aquifer above the upper level of the silo. The barrier serves to create a hydraulic barrier between the sealed silo and the groundwater in the Quaternary stratum during the period following the sealing of the silo.

The barrier will comprise a layer of clay over a reinforced concrete slab to be placed on top of the silo. The top of the layer will reach almost to ground level.

5.3.3.6 O6 – Backfill material at aquifer level

Natural materials that have remained from the excavation process (gravel) or similar materials will be used to fill the void that arises after the sealing of the disposal silo between the top edge of the barrier between the silo and the aquifer and the surface. The purpose of this is to re-establish a primary state in the layer above the clay barrier, the main reason being to avoid having a visible clay layer that could represent an interesting raw material in later years.

5.3.3.7 O7 – Structure for excavation of construction pit

For construction of the disposal unit (silo), it is necessary to properly excavate a construction pit and to protect it against the intrusion of groundwater from the Quaternary stratum.

The conceptual design [6] plans a preliminary thick-walled reinforced concrete diaphragm along the entire depth of the silo excavation in order to secure the excavation work. A reinforced concrete invert will be constructed at the bottom of the silo. The reinforced concrete diaphragm will shield the construction pit from the intrusion of groundwater from the Quaternary stratum.

During excavation, steps should also be taken to relieve the hydrostatic pressure on the bottom of the excavated pit; relief boreholes are therefore planned.

The relief of pressure in the rock for the purposes of preventing hydraulic fracturing of the floor during excavation of the construction pit will be ensured by pumping the groundwater from the relief wells.

The locations, number and depth of the relief boreholes/wells will be determined for the phase of obtaining the construction permit on the basis of hydrogeological analysis, supported with pumping tests. The analysis will also be used to determine the timetable, i.e. the beginning of pumping, to ensure that the pressure relief is always undertaken sufficiently before the excavation.

During construction there will be regular checks to ensure that the relief wells are working properly and that the desired state is being attained. The number of boreholes will be modified as necessary, and new boreholes added and the time of relief pumping adjusted.

The pressure relief boreholes will be temporary, and will be demolished as the excavation of the silo progresses, for which reason there is no plan for any special conditions; they merely perform their function of having water pumped from them.

5.3.3.8 O8 – Flood protection: embankment, raising of silo

This SSC shields the disposal unit (silo) during operation from the probable maximum flood for the site. It should also be sufficiently solid that facilities built on it comply with the required seismic safety standards, and should ensure adequate resistance to lateral erosion caused by floods. The raising of the silo above the level of the embankment also provides the disposal silo with additional protection against flooding and can have other functions at the same time (providing a perimeter around the silo, etc.).

According to the conceptual design, [6] the plateau will be 155.2 m above sea level and the silo parapet 1.3 m higher than the top of the embankment. It constitutes a protective perimeter and provides additional protection against flooding.

5.3.3.9 O9 – Hall above silo

This roof is an SSC that shields the construction pit, silo and disposal/transport equipment from atmospheric impact during operation. It covers the entire floor area of the silo, along with the handling/loading areas.

5.3.3.10 O10 – Disposal/transport equipment

This SSC enables FPs to be disposed of and correctly positioned in the silo, and ensures safe operation; it also enables the transport of various materials that need to be delivered to the silo during operation (backfill materials, etc.). Where necessary, it also provides for the transport of workers to and from the silo. The possibility also has to be envisaged of LILW being placed in the silo without being packaged into FPs (e.g. individual large components).

There are plans [6] for the deployment of a portal crane that can be controlled from the control room or locally.

5.3.3.11 O11 – Electrical installations

These are all SSCs within the disposal facility that carry electricity from the electricity distribution boxes at the disposal facility to the devices being used. They include electrical installations of various voltages, such as:

- lighting installations,
- electrical motor installations,
- electrical heating machinery.

Electrical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.3.12 O12 – Fire protection system

This is an SSC that provides protection against fire in the disposal facility. It includes the entire fire safety system within the disposal facility.

Fire protection must adhere to the defence-in-depth principle such that the following are in place:

- measures that prevent the outbreak of fire,
- rapid detection, control and extinguishing of all fires, and
- prevention of the spread of fire and its consequences in and to any area where it could place the safety of the repository at risk.

Building fire safety:

- This should be designed in such a way that a building is as safe from fire as possible. Where necessary, the building should be divided into fire compartments and fire cells.
- Fire compartments must prevent a fire from adversely affecting safety-related equipment, and must separate redundant or diverse lines of individual safety systems from each other.
- A building that houses radioactive materials and in which a fire could give rise to radioactive releases should be designed so that releases are kept to a minimum in the event of fire.
- The design should ensure that there are fire routes for all those tasked with tackling a fire as well as evacuation routes for personnel within the facility.

5.3.3.13 O13 – Physical security systems

This SSC covers the provision of physical and technical security at the disposal facility.

5.3.3.14 O14 – Monitoring systems

This covers all SSCs for monitoring at the disposal facility, including:

- operational monitoring,
- environmental monitoring,
- monitoring of the state of the facility.

5.3.3.15 O15 – Mechanical installations

This SSC contains the following installations located at the disposal facility:

- ventilation and air conditioning,
- hydrant system.

Mechanical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.3.16 O16 – Radiation protection system

The entire area of the disposal facility is a radiologically controlled area. O16 comprises all SSCs that enable the establishment, operation and control of a radiologically controlled area.

5.3.3.17 O17 – Telecommunications systems

Telecommunications systems include telecommunications installations at the disposal facility, such as:

- telephone and computer installations (also including software),
- voice communication and public address systems,
- antenna installations.

5.3.4 SSC DESCRIPTION: TECHNOLOGICAL FACILITY

5.3.4.1 T1 – Building / building structure

The T1 SSC comprises the technological facility building structure. This facility is intended for: [9]

- the temporary storage and remediation of any damaged waste containers,
- measurements,
- monitoring of technological procedures, and
- other required technological and service functions of the repository, and functions for ensuring nuclear and radiation safety.

The technological facility is also the control point for entry to and exit from the radiologically controlled area. The technological facility will be constructed in two phases.

TF Phase 1:

- control point with accompanying premises,
- storage of secondary radioactive waste and measurement room,
- service, energy and technical areas serving the technological facility during Phase 1, and
- common areas and utility rooms.

TF Phase 2:

- back-up storage capacities with hot workshop and secondary LILW storage area,
- ventilation control room and measurement room for operational requirements during Phase 2.

5.3.4.2 T2 – Flood protection

This SSC shields the technological facility during operation from the probable maximum flood for the site. It should also be sufficiently solid that facilities built on it comply with the required seismic safety standards, and should ensure adequate resistance to lateral erosion caused by floods.

Under the conceptual design, [6] all safety-related facilities (disposal and technological facilities) will be built on a backfilled flood-protection plateau that protects them against probable maximum flood (PMF). The upper edge of the embankment is 155.2 m above sea level.

5.3.4.3 T3 – Electrical installations

These are all SSCs within the technological facility that carry electricity from the electricity distribution boxes at the technological facility to the devices being used. They include electrical installations of various voltages, such as:

- lighting installations,
- electrical motor installations,
- electrical heating machinery,
- back-up power installations,
- electrical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.4.4 T4 – Mechanical installations

This SSC includes the following installations located at the technological facility:

- water supply system,
- heating,
- ventilation and air conditioning,
- mechanical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.4.5 T5 – Sewerage systems

This SSC comprises all structures, systems and components within the technological facility serving the internal sewerage system for the drainage and treatment of waste water. This system will be connected to the public sewerage system.

5.3.4.6 T6 – Physical security systems

This SSC covers the provision of physical and technical security at the technological facility.

5.3.4.7 T7 – Radiation protection system

The area of the technological facility lies partly in the radiologically controlled area and partly outside it. T7 comprises all SSCs that enable the establishment, operation and control of the radiologically controlled area, and the performance of the required radiation protection activities within the radiologically controlled area of the technological facility.

5.3.4.8 T8 – Telecommunications systems

Telecommunications systems include telecommunications installations at the technological facility, such as:

- telephone and computer installations,
- voice communication and public address systems,
- antenna installations.

5.3.4.9 T9 – Fire protection system

This SSC covers the fire safety requirements at the technological facility.

Fire protection must adhere to the defence-in-depth principle such that the following are in place:

- measures that prevent the outbreak of fire,
- rapid detection, control and extinguishing of all fires, and
- prevention of the spread of fire and its consequences in and to any area where it could place the safety of the repository at risk.

Building fire safety:

- This should be designed in such a way that a building is as safe from fire as possible. Where necessary, the building should be divided into fire compartments and fire cells.
- Fire compartments must prevent a fire from adversely affecting safety-related equipment, and must separate redundant or diverse lines of individual safety systems from each other.
- A building that houses radioactive materials and in which a fire could give rise to radioactive releases should be designed so that releases are kept to a minimum in the event of fire.

- The design should ensure that there are fire routes for all those tasked with tackling a fire as well as evacuation routes for personnel within the facility.

5.3.4.10 T10 – Monitoring

This SSC comprises all the necessary structures, systems and components that enable the performance of operational, radiological and environmental monitoring at the technological facility and the appropriate storage of the information obtained. It should also enable comparisons to be made and information to be released to the public, where necessary.

5.3.5 SSC DESCRIPTION: ADMINISTRATIVE AND SERVICE BUILDING

5.3.5.1 US1 – Building / building structure

The US1 SSC comprises the administrative and service building and structure. Under the conceptual design, [6] the administrative part of the facility contains the premises and systems serving repository management activities, and the related service and administrative activities, as well activities to control the entry of items, persons (personnel and visitors) and vehicles (RW-carrying and other vehicles) and to exercise surveillance of the repository.

The service part of the facility is intended for energy activities, fire water supply, collection of municipal waste, storage of equipment and geological samples (cores) and a workshop.

The building is located outside the radiologically controlled area.

5.3.5.2 US2 – Flood protection

This SSC shields the service building from floods during operation, with a specific return period for the site. It should also be sufficiently solid that facilities built on it comply with the required seismic safety standards, and should ensure adequate resistance to lateral erosion caused by floods.

According to the preliminary design, [31] protection of the administrative building against a flood with a 1,000-year return period is sufficient. For reasons of cost-effectiveness of construction and the fact that a single plateau is to be constructed, under the conceptual design [6] the administrative and service building will be constructed on a backfilled flood-protection plateau, with the upper edge of the plateau standing 155.2 m above sea level. This provides protection against probable maximum flood.

5.3.5.3 US3 – Electrical installations

These are all SSCs within the administrative and service building that carry electricity from the electricity distribution boxes at the technological facility to the devices being used. They include electrical installations of various voltages, such as:

- lighting installations,
- electrical motor installations,
- electrical heating machinery,
- electrical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.5.4 US4 – Mechanical installations

This SSC contains the following installations located within the administrative and service building:

- water supply system,
- heating,
- ventilation,
- mechanical installations must comply with the fire protection requirements contained in the fire safety study.

5.3.5.5 US5 – Sewerage systems

This SSC comprises all structures, systems and components within the administrative and service building serving the internal sewerage system for the drainage and treatment of waste water. This system will be connected to the public sewerage system.

5.3.5.6 US6 – Physical security system

This SSC covers the provision of physical and technical security at the service building.

5.3.5.7 US7 – Telecommunications systems

Telecommunications systems include telecommunications installations at the service building, such as:

- telephone and computer installations,
- voice communication and public address systems,
- antenna installations.

5.3.5.8 US8 – Fire protection system

This SSC covers the fire safety requirements at the administrative and service building.

Fire protection must adhere to the defence-in-depth principle such that the following are in place:

- measures that prevent the outbreak of fire,
- rapid detection, control and extinguishing of all fires, and
- prevention of the spread of fire and its consequences in and to any area where it could place the safety of the repository at risk.

Building fire safety:

- This should be designed in such a way that a building is as safe from fire as possible. Where necessary, the building should be divided into fire compartments and fire cells.
- Fire compartments must prevent a fire from adversely affecting safety-related equipment, and must separate redundant or diverse lines of individual safety systems from each other.
- The design should ensure that there are fire routes for all those tasked with tackling a fire as well as evacuation routes for personnel within the facility.

5.3.6 SSC DESCRIPTION: PHYSICAL SECURITY FACILITIES

5.3.6.1 F1 – Outer perimeter fence

This SSC runs along the outer perimeter of the LILW repository site and restricts direct access to the site itself (the controlled area).

5.3.6.2 F2 – Inner perimeter fence

This SSC separates the radiologically controlled area from the rest of the repository area within the LILW repository site.

5.3.6.3 F3 – Other physical security systems

This SSC comprises all other structures, systems and components important for the provision of physical and technical security across the wider area of the repository.

5.3.7 SSC DESCRIPTION: EXTERNAL ARRANGEMENTS

5.3.7.1 Z1 – Embankment

This SSC shields the entire repository from floods during operation, with a specific return period for the site. It should also be sufficiently solid that facilities and infrastructure built on it comply with the required seismic safety standards, and should ensure adequate resistance to lateral erosion caused by floods.

5.3.7.2 Z2 – Transport-related arrangements

This SSC comprises all arrangements that enable and ensure the implementation of all types of transport within the inner perimeter of the repository.

5.3.7.3 Z3 – Planted areas

This SSC covers all planted areas at the LILW repository. Where necessary, it also covers the area outside the outer perimeter of the repository.

5.3.7.4 Z4 – Exterior lighting

This SSC comprises all structures, systems and components that provide exterior lighting to the LILW repository.

5.3.7.5 Z5 – Collection and drainage of rainwater runoff and waste water

These are SSCs that enable the proper collection and, where necessary, control and drainage of rainwater runoff.

The conceptual design envisages the rainwater runoff being channelled from the roofs of all the buildings at the repository site via sand catchers to a drainage well. Rainwater from reinforced areas is channelled to the drainage well via oil separators.

5.3.7.6 Z6 – External connection to water supply system and hydrant network

The external connection to the water supply system runs within the perimeter of the repository and serves to supply all facilities at the repository with drinking water and firefighting water; at the same time, it also serves as an external hydrant network for extinguishing fires. The installation and number of hydrants must comply with the fire safety study.

5.3.8 SSC DESCRIPTION: INFRASTRUCTURE LINES AND CONNECTIONS

5.3.8.1 I1 – Electricity

This SSC comprises electrical connections and lines to specific distribution boxes and users.

The conceptual design provides for two electricity connections. The first (MV connection) connects the repository to the power system, while the second (LV connection) connects the pumping station for sewage waste water from the new pumping station.

The LILW repository's electricity connections must ensure energy supply to all structures, systems and components required for the operation of the repository as an independent nuclear facility.

The electricity connections as a whole comply with the applicable technical standards and guidelines and with the requirements of Elektro Celje, which operates the electricity lines and supplies electricity to this area, as follows:

- connection to the existing transformer station,
- installation of a transformer (400 kVA) on the repository plateau,
- installation of new MV and LV cabinets,
- electricity transmission along MV lines.

Supply from the transformer station at Kostak dump (20/0.4 kV with transformer power of 1 MVA) as follows:

- MV connection (20 kV) for the repository itself (new ARAO transformer station 20/0.4 kV with transformer power of 400 kVA),
- LV connection (0.4 kV) for the new sewage pumping station (type design with two 5.5 kW pumps).

The safety-related systems and components must also be supplied with the necessary electricity from a diesel generator as an emergency source of power, during all facility states and during design-basis events. If the external power supply is lost, important SSCs are supplied from the diesel generator. Electricity supply from the diesel generator is envisaged for the water-collecting reservoir pumps in the technological facility, for the lift and pumps in the disposal facility, for the control pool, and for the fire water pumping station in the administrative and service building. The diesel generator for back-up supply must have guaranteed stocks of fuel to enable 24-hour operation at full power. In the event of a failure in the external supply, the acceptance and disposal of LILW ceases with immediate effect, and non-disposal activities in the area of the silo are ceased as soon as possible (and no later than eight hours after failure).

For the provision of power to sensitive users that require a guaranteed constant supply, an appropriate UPS unit is envisaged for each functional unit of the repository to deal with any failure in the network or the diesel generator voltage.

5.3.8.2 I2 – Telecommunications

Under the conceptual design, [6] repository facilities need to be connected to the communications network. The LILW repository will be connected to the existing telecommunications network via a new optical cable running between the ditches at the entrance to the Kostak dump and the repository's administrative and service building. Cable ducts will be constructed along the route in the form of a PE-HD pipe (the optical cable will be laid inside the pipes).

5.3.8.3 I3 – Water supply system

Under the conceptual design, [6] connection to the water mains is designed so that the repository is connected to the mains in the area of the reconstructed Vrbina road via a water gauging shaft.

The pipelines are to be laid on a bed of fine sand. Blue PVC tape bearing the words “POZOR VODOVOD” (WARNING: WATER MAINS) will be placed along the basic embankment above the axis of the pipeline.

The mains pipe runs through a shaft into which a water gauge is to be incorporated.

5.3.8.4 I4 – Faecal sewage system

Under the conceptual design, [6] the municipal sewerage system at the LILW repository is designed in such a way that it removes sanitary water from facilities and process water collected in collectors (collection tank in the silo, floor drain sump in the technological facility [Phase 2], control pool and sanitary tank in the technological facility [Phase 1]). Controls are carried out on the water collected in the pool. If it meets the conditions prescribed for release, it is released into the public sewerage system.

Because of the configuration of the terrain and the obstacles along the route, the public sewerage system is divided into:

– a free-fall/gravitational section: from the LILW repository perimeter to the pumping station at the entrance to Kostak municipal waste collection centre, and
– a pressurised section: from the pumping station to the connection to the existing Libna pumping station.

With the construction of the new repository, the entire sewerage system from all facilities will be connected to the central sewerage system (towards Spodnji Stari Grad). Owing to the differences in elevation between the new and existing sewerage systems, an underground pumping installation is planned on the right-hand side at the entrance to the Kostak dump.

5.3.8.5 I5 – Rainwater runoff system

Under the conceptual design, [6] the rainwater runoff system leads to a drainage well at the repository. Drainage for the car park is arranged so that water flows along the kerbs to the road drains and then through an oil separator to the drainage well.

The drainage of rainwater runoff within the immediate LILW disposal area should be divided as follows:

- the drainage of traffic surfaces, the water from which must be treated in a coalescing oil separator before release, and
- roof water, which does not need to be treated in a coalescing oil separator. This reduces the amount of stormwater runoff that has to be treated prior to release.

Stormwater (treated) and roof runoff then flow into the common infiltration field planned in the south-east part of the LILW repository site.

5.3.8.6 I6 – Road connection

Under the conceptual design, [6] access to the repository is via a road connection from the Vrbinka road. The Vrbina road is to be reconstructed from the road that leads to the repository up to the planned Spodnji Stari Grad roundabout (length of 460 m).

5.3.9 SSC DESCRIPTION: MONITORING FACILITIES

5.3.9.1 M1 – Monitoring

This SSC comprises all structures, systems and components that enable operational and environmental monitoring to be carried out in the external part of the repository, and the appropriate storage of the information obtained. It should also enable comparisons to be made and information to be released to the public, where necessary.

5.3.10 SAFETY CLASSIFICATION OF SSCS

In accordance with the JV5 rulebook, safety classification is the classification of SSCs in line with the required safety functions for ensuring nuclear safety, and classification into safety classes with regard to their importance to nuclear safety.

As required by the graded approach and the JV5 rulebook, [1] which provides that all SSCs should be classified into safety classes, there are two safety classes defined for the LILW repository. These are:

- safety-related SSCs: this category includes SSCs whose termination would have a major impact on the results of the safety assessment, or would require a significant change to the models used in the safety assessment,
- non-safety-related SSCs: this category includes SSCs whose termination would not have a major impact on the results of the safety assessment, or would not require a significant change to the models used in the safety assessment.

As required by the graded approach and the JV5 rulebook, the safety classification was conducted on the basis of the results of safety analysis and an engineering assessment by a group of experts in various fields who were also involved in the preparation of the design bases. The graded approach means that the safety categorisation of SSCs has not been carried out.

The table below illustrates the safety classification for the individual SSCs identified in the previous section.

Table 5.7: Safety classification and safety functions of individual SSCs

SSC designation	SSC description	Safety function (Section 5.2.8)	Safety classification	Passive (P) or active (A) function	Remarks
O1	Final package	P, C, H, I, S, Sh	SR	P	The SSC performs its functions during operation and after closure. The FP represents one of the key passive safety elements for the repository. The FP will be produced in a controlled atmosphere and its properties will be easily demonstrable. Failure of the SSC would demand a major change in the nearfield model, which would lead to a change in the results of the safety analysis.
O2	Backfill	P, C, H, S, Sh	NSR		The SSC performs its functions during operation and after closure. The classification is non-safety-related, as its failure would result in very minor changes to the safety analysis models, and would have a minimal impact on the results.

O3	Silo	P, C, H, I, S	SR	P	The SSC performs its functions during operation and after closure. The SSC is safety-related. The failure of the SSC would bring major changes to the models and the results of the safety analysis.
O4	Drainage system	H	SR	A	During operation the SSC is safety-related, as it ensures that the disposal silo is dry. The failure of the SSC would require a change in the entire disposal concept, and would affect the models used in the safety analysis.
O5	Barrier between silo and aquifer	P, C, H, I	SR	P	The barrier performs the function of isolating the silo (and therefore the waste) from the aquifer. The SSC performs its functions during operation and after closure. The SSC is safety-related, as its failure would change the models used and the results of the safety analysis.

O6	Backfill material at aquifer level	I	NSR		The backfill material performs the function of isolating the silo (and therefore the waste) from the aquifer. The SSC performs its functions during operation and after closure. The SSC is defined as non-safety-related, as its failure would not have a major impact in changing the safety analysis models.
O7	Structure that enables a construction pit to be excavated	S	NSR		The SSC performs its functions during construction. The SSC is classified as non-safety-related, because it was not taken into account in the safety analysis; the structure provides for the excavation and construction of the disposal silo, and merely represents an added value.
O8	Flood protection – embankment	H, Su	SR	P	The SSC performs its functions during operation. Together with SSCs T2 and US2, this SSC constitutes a single

					embankment which, as a result of a systematic approach, is divided into three sections depending on the repository facility. The SSC is defined as safety-related, as during operation it ensures that the silo remains dry in the event of major floods. In the event of failure, it would be necessary to change the concept of the safety analysis.
O9	Hall above silo	H, Sh, Su	NSR		The hall above the silo is a roof that protects the silo from the elements. The SSC is defined as non-safety-related, as its failure would entail only a minor change in the safety analysis: precipitation could fall into the disposal silo, and the maintenance of a dry state would be taken over by the drainage system.
O10	Disposal/transport equipment	Su	SR	A	The SSC performs its functions during operation.

					The SSC is safety-related, as its failure would lead to an accident.
O11	Electrical installations	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis. A back-up power supply is provided.
O12	Fire protection system	Su	SR	A	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure would lead to an accident.
O13	Physical security systems	Se, I, Su	SR	A	The SSC performs its functions during operation and after closure. The SSC is defined as safety-related, as its failure would lead to an accident.
O14	Monitoring systems	Su	NSR		The SSC performs its functions during operation and after closure (period of active controls).

					The SSC is identified as non-safety-related, as its failure has no impact on the safety assessment of the repository. In the event of the failure of the system, it is necessary to restore it as soon as possible and to recontrol the situation.
O15	Mechanical installations	Su	NSR		The SSC performs its functions during operation and after closure. The SSC is identified as non-safety-related, as its failure has no impact on the safety of the repository.
O16	Radiation protection system	Su	SR	A/P	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure has an impact on the safety of the repository.
O17	Telecommunications systems	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure has no

					impact on the safety of the repository.
T1	Building / building structure	P, I, S, Sh, Se	SR	P	The SSC performs its functions during operation. The SSC prevents the release of radiation into the environment. Its failure would lead to a change in the safety analysis models, and in their results.
T2	Flood protection	H, Su	SR	P	The SSC performs its functions during operation. Together with SSCs O8 and US2, this SSC constitutes a single embankment which, as a result of a systematic approach, is divided into three sections depending on the repository facility. The SSC is defined as safety-related, as during operation it ensures that the silo remains dry in the event of major floods. In the event of failure, it would be necessary to change the

					concept of the safety analysis.
T3	Electrical installations	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
T4	Mechanical installations	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure has no impact on the safety of the repository.
T5	Sewerage systems	P, Su	SR	A	A system for the capture and control of waste water that could be in any way contaminated must be provided for as part of the sewerage systems. The SSC performs its functions during operation. The SSC is defined as safety-related, as it ensures the controlled management of potential contamination. Its failure would have an impact

					on the safety analysis and its results.
T6	Physical security systems	I, Se, Su	SR	A	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure would lead to an accident.
T7	Radiation protection system	Su	SR	A/P	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure has an impact on the safety of the repository.
T8	Telecommunications systems	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
T9	Fire protection system	Su	SR	A	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure would lead to an accident.
T10	Monitoring	Su	NSR		The SSC performs its functions

					during operation. The SSC is identified as non-safety-related, as its failure has no impact on the safety assessment of the repository. In the event of the failure of the system, it is necessary to restore it as soon as possible and to recontrol the situation.
US1	Building / building structure	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US2	Flood protection	Su	NSR		The SSC performs its functions during operation. Together with SSCs O8 and T2, this SSC constitutes a single embankment which, as a result of a systematic approach, is divided into three sections depending on the repository facility.

					The SSC is identified as non-safety-related, as its failure (under the administrative and service building) would not entail any changes to the safety analysis.
US3	Electrical installations	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US4	Mechanical installations	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US5	Sewerage system	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US6	Physical security systems	Se, Su	NSR		The SSC performs its functions

					during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US7	Telecommunications systems	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
US8	Fire protection system	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
F1	Outer perimeter fence	Se	SR	P	The SSC performs its functions during operation. The SSC is defined as safety-related, as its failure would lead to an accident.
F2	Inner perimeter fence	Se	NSR		The SSC performs its functions during operation and after closure (period of

					active and passive controls). The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
F3	Other physical security systems	Se	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z1	Flood protection	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z2	Transport-related arrangements	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z3	Planted areas	Su	NSR		The SSC performs its functions during

					operation and after closure. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z4	Exterior lighting	Se, Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z5	Collection and drainage of rainwater runoff	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
Z6	External connection to the water supply system and hydrant network	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
I1	Electricity	Su	NSR		The SSC performs its functions during operation.

					The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
I2	Telecommunications	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
I3	Water supply system	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
I4	Sewage system	Su	NSR		The SSC performs its functions during operation. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
I5	Rainwater runoff system	Su	NSR		The SSC performs its functions during operation. The SSC is identified as

					non-safety-related, as its failure would not entail any changes to the safety analysis.
I6	Road connection	Su	NSR		The SSC performs its functions during operation and after closure. The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.
M1	Monitoring	Su	NSR		The SSC performs its functions during operation and after closure (period of active controls). The SSC is identified as non-safety-related, as its failure would not entail any changes to the safety analysis.

5.4 DESIGN AND CONSTRUCTION

The technical requirements for SSCs defined above are given in Section 11 of the design basis, [2] and are divided into the following:

- operational limits and conditions,
- requirements regarding facilities and structures,
- requirements regarding seismic loads,
- requirements regarding architectural solutions, landscaping and human activities,
- requirements regarding technological systems,
- requirements regarding mechanical installations and equipment,
- requirements regarding electrical installations and equipment,
- requirements regarding computerised control and surveillance,
- requirements regarding telecommunications,
- requirements regarding the distribution of facilities, systems and devices,

- requirements regarding radiation protection and dose limits,
- requirements regarding environmental protection and operational monitoring,
- requirements regarding fire protection,
- requirements regarding flood-protection and protection against meteorological impacts,
- requirements regarding occupational health and safety,
- requirements regarding the physical security of facilities, restriction of access to facilities, and restrictions on the introduction and removal of materials,
- requirements regarding the provision of unobstructed access,
- requirements regarding safety analysis and emergency preparedness,
- requirements regarding functional analysis,
- requirements regarding documentation,
- requirements regarding transport of waste,
- other requirements.

Detailed descriptions of safety-related SSCs are presented in Section 6 of this draft safety analysis report. Section 4 of the design bases [2] also presents the general design conditions and principles, which are summarised in Section 5.2 of this document.

The construction of all safety-related facilities is presented in detail in the conceptual design [6] and summarised in Section 6 of this document.

The basis for the seismic classification of engineered barriers is provided in Section 4.5 of this document.
Individual safety-related SSCs that perform other safety functions alongside structural functions are described in Section 6 of this document.

The decommissioning of the repository is described in Section 16 of this document.

The closure of the LILW repository is described in Section 12 of this document.

The solutions proposed in the conceptual design [6] were checked with safety analysis, which is described in Section 7 of this document. This provides an assurance that the planned repository satisfies the design bases. [2]

5.4.1 HUMAN FACTOR

The human factor has been taken into account to the greatest possible extent in the planning of the LILW repository.

The facilities are designed to meet the technological conditions and requirements with their dimensions, capacities and selection of finishing work. At the same time, special attention was devoted in the spatial arrangement of the structures and in their architectural design to their appropriate harmonisation and adaptation to the surrounding environment. A special architectural commission was also established for this purpose.

It is anticipated that the facilities will provide appropriate conditions for users of the facilities and other persons to use them, to spend time in them and to work in them in a healthy, safe and comfortable manner, while meeting all the essential requirements for buildings [6] (mechanical robustness and stability, fire safety, hygienic and health protection and environmental protection, safety in use, noise protection, energy and heat conservation). All of the aforementioned requirements will also be taken into account in the subsequent design phases.

The design of the repository has at all times made use of a conservative deterministic approach, mostly supported by calculations and analysis of safety-related design parameters and processes at the facility that arise after postulated initiating events. By means of judgments, analysis and calculations, it should be verified and confirmed that the permitted values of the basic safety parameters have not been exceeded, and that adequate safety limits have been provided.

The approach to the application of the criteria for achieving the right design solutions and safety limits was dependent on the type of design activity, and primarily consisted of the following in terms of individual types:

1. the use of standard analysis and calculations (e.g. in accordance with the Eurocodes) with safety limits in the forms of standardised safety factors,
2. the use of established engineering analysis (e.g. hydraulic, radiation) with the consideration of conservative input data and with the guidance of design towards solutions that ensure a safety limit (e.g. increasing the diameter of the flow element, extra wall thickness), and
3. the introduction of established design solutions on the basis of engineering judgments, where the compliance and the safety margin for the envisaged design events and states are known from reference facilities.

5.5 QUALIFICATION OF SSCs IN TERMS OF ENVIRONMENTAL IMPACT

Within the framework of the safety analysis (Section 7), individual SSCs are connected with their safety functions (these are defined in Section 5.3.10 of this draft safety analysis report) via individual properties that are ascribed to them. The repository's environmental impact was reviewed within the framework of the safety analysis, under the assumed conditions, together with the degradation of (the impact of the environment on) individual SSCs (Section 7 of this draft safety analysis report). This confirmed the individual safety functions of the SSCs as acceptable.Possible models of degradation of individual SSCs and the repository as a whole were also presented. A case of SSC failures that might occur for various reasons was also analysed: the scenario of the early failure of engineered barriers.

A list of materials and equipment that will be used in the construction of the LILW repository will be enclosed in the next phase of the project. The materials and the equipment alike must comply with the design bases [2] and must meet all the requirements of the Environmental Protection Act [53] and other legislation, and will additionally be stated in the environmental consent.

The following also needed to be taken into account in the planning of the repository:

- ensuring that as little secondary waste as possible is generated during construction and operation, both radioactive and non-radioactive,
- making it possible for secondary waste to be separated as required by the legislation,
- ensuring that construction does not create major degradation of land and aquatic ecosystems in the vicinity of the activity,
- observing all the requirements of the Decree on waste [54] during construction.

The following were also taken into account as appropriate:

- international standards, principles and directives,
- recommendations and studies,
- spatial planning acts, opinions and design conditions,

and are presented in detail in Section 11.12.1 of the design bases. [2]

The degradation of the repository after closure and its environmental impact are examined in detail in the safety analysis for the LILW repository (Section 7 of this document).

Individual SSCs and their classifications in terms of environmental impact are described in Section 6 of this draft safety analysis report.

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