PROJECT 'PURCHASE OF STUDIES FOR THE PREPARATION OF A DESIGNATED SPATIAL PLAN AND THE ASSESSMENT OF IMPACT'

PROJECT PART: STUDIES NECESSARY FOR THE ESTABLISHMENT OF THE RADIOACTIVE WASTE REPOSITORY

ACTIVITY 3. Comparison of the repository locations

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ABBREVIATIONS

ALT	Altküla site
IAEA	International Atomic Energy Agency
IDDF	Intermediate Depth Disposal Facility
NSDF	Near Surface Disposal Facility
PAL	Paldiski site
PED	Pedase site

Introduction

The ultimate goal of the project is to select the most suitable location of the establishment of the disposal facility for the radioactive waste accumulated in Estonia. The siting is performed using a step wise approach. According to the IAEA guidance (IAEA Safety Standards Series No SSG-29 'Near Surface Disposal Facilities for Radioactive Waste') the site selection process is usually divided into four main stages: the conceptual and planning stage, the area survey stage, the site investigation stage, the stage of detailed site characterization leading to site confirmation for construction of the disposal facility. Site characterization should contribute to a comprehensive description of the site that is sufficient to support development of the safety case and its supporting assessments. Therefore, the studies needed for further development of waste disposal program are planned.

As a result of Activity 1, "Determining the three most optimal locations for the repository," two possible sites, Altküla (ALT), and Pedase (PED) were selected for the future disposal facility (Figure 1). Paldiski (PAL) as the current location of the naval nuclear reactors and radioactive waste interim storage facility was pre-selected by the stakeholders as one potential repository site. Selecting the most suitable location for the establishment of the repository is the goal of the next stage. The selection must be in accordance with the local government designated spatial plan and the related assessment of impact, including the strategic assessment of environmental impact of the establishment of the repository. By implementing Activity 2 "Studies of the three repository locations" the necessary data were collected that will serve as the basis for the preparation of these documents and making a decision in principle.

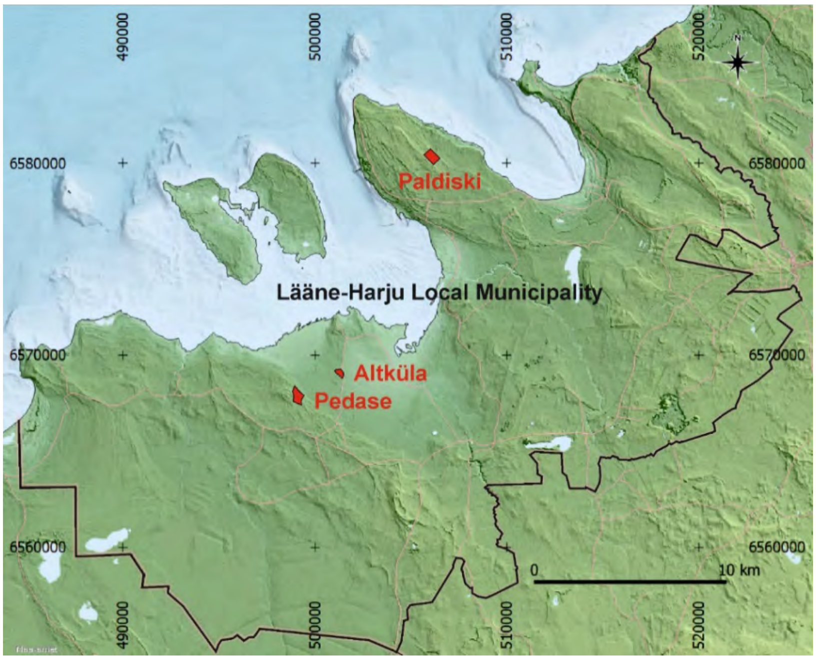

Figure 1. Location of three possible disposal facility locations in the area of Lääne-Harju local municipality.

The objectives of Activity 3 are to further study the suitability of previously identified potential sites by conducting a comparative analysis of alternatives, including the “zero” option, taking into account the data obtained during the implementation of Activity 1 and Activity 2. In addition, another goal is to outline the future detailed studies in order to get ready to designing the repository and preparing the final Safety Assessment Report and Safety Case needed for licence application.

1. Sub-activity 3.1: Zero alternative: an overview, if the repository will not be established

The “zero” option is an alternative to disposal of radioactive waste. It considers situation when, without the construction of a disposal facility for radioactive waste, the conserved dismantled reactor compartments and the available radioactive wastes will continue to be stored at the Paldiski site. The objective of the conducted study was an analysis of safety, environmental, economic and other factors, evaluation of the possible disadvantages and advantages related to the implementation of the "zero" alternative, compared to the construction of the disposal facility according to the plan. This option becomes relevant when, for some reason, a site for the radioactive waste disposal facility is not selected and a decision on the establishment of the facility is not taken or postponed for a certain period of time.

The work was performed by Stasys Motiejūnas (UAB EKSORTUS) and reviewed by Egidijus Babilas (LEI), the detailed results are presented in an Appendix 1.

1.1. Definition of the “zero” option

According to the approved plan, the reactor compartments will be dismantled in 2040-2050. By that time Estonia should have a radioactive waste disposal facility, which could accommodate waste arising from decommissioning of the reactor compartments. Meaning of the “zero” option in the framework of the current activity is that the disposal facility is not constructed as scheduled (i.e. by year 2040). It can happen due to the following reasons:

1. failure of the siting programme (the proposed site and disposal program is not agreed with stakeholders and not confirmed);
2. no available funding for building the disposal facility;
3. appearance of new relevant factors in Estonia influencing the radioactive waste disposal program, for example, identification of new radioactive waste sources which require other disposal solutions.

Based on preliminary considerations within Sub-activity 5.1 of the current project, it was concluded that the optimal prolonged storage period of reactor compartments is up to 2100 years. It was assumed that the life of the Main Technological Building under “zero” option will expire by 2100 (140 years from the reactor commissioning date). Throughout the entire storage period the Main Technological Building, the structures of sarcophagi and the temporary storage of radioactive waste must act as barriers to the possible spread of radioactive substances and ensure the safety. Based on the experience of assessing the durability of similar type of building structures, the recommended time from the moment of construction of the structures to the exhaustion of its resources for industrial buildings made of reinforced concrete structures is estimated to be about 100 years. Considering ageing process a new engineering study has to be done if prolongation of the storage until 2100 would be decided. To ensure the safe storage of the reactor compartments and radioactive waste in the facility after 2050, large-scale reconstruction of the facility will be required.

A rather different situation than the one examined in Sub-activity 5.1 could arise if, for some reason, a decision was made to dismantle the reactors without making a decision to build a disposal facility. For example, this could potentially happen if it is decided that the reactors are unsafe and there is no way to fix the problems. In this case a new radioactive waste management facility will be needed. It would include equipment for waste handling and conditioning as well as premises for storage.

1.2. Compliance with EU policy

The COUNCIL DIRECTIVE 2011/70/EURATOM of 19 July 2011 establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste states that it should be an ethical obligation of each Member State to avoid any undue burden on future generations in respect of radioactive waste, including any radioactive waste expected from decommissioning of nuclear installations. Through the implementation of this Directive Member States have to demonstrate that they have taken reasonable steps to ensure that that objective of the Directive is met. The Directive also states, that the storage of radioactive waste, including long-term storage, is an interim solution, but not an alternative to disposal.

In conclusion, it is necessary to note that, considering the international obligations and national policy, a clear priority must be given to disposal over long-term storage. Long term storage is not regarded as a sustainable solution.

1.3. Safety and security

Containment and isolation of the waste is provided by means of a number of physical barriers of the disposal system. The engineered and natural barriers that make up the radioactive waste disposal system are the waste form, the packaging, the backfill, and the host environment including geological formation. The performance of these physical barriers is achieved by means of diverse physical and chemical processes together with an option of operational controls. Safety functions are provided by means of a physical or chemical properties and process that contributes to containment and isolation, such as: water impermeability; limited radionuclide dissolution, leach rate and solubility, retention and retardation of radionuclide migration. The overall performance of the disposal system is not unduly dependent on a single safety function. The physical elements and their safety functions are complementary and work in combination.

The main advantage of waste disposal over waste storage is the application of the principle of passive safety in the concepts of waste disposal. The long-term safety of the disposal facilities after closure is ensured by passive means to the fullest extent possible. The disposed wastes are much less vulnerable in case of human breach. An important safety factor is the significant increase in recent years of the threat of terrorism or sabotage. Underground disposal facilities are much less vulnerable than above ground storage facilities or closed reactors. Therefore, waste disposal is preferred in order to achieve the highest safety level and minimize risks.

1.4. Environmental factors

Possible environmental impacts were analysed in detail in Activity 2 of this project. Sub-activities 2.10, 2.11, 2.12 and 2.14 were dedicated to the investigation of various specific environmental impacts related to radioactive waste disposal. The conducted studies did not reveal any significant impact. Only minor amount of energy resources will be needed for surveillance, maintenance and monitoring of the closed disposal facility. No other resources will be needed. In contrast, the energy resources are needed to maintain the reactor building in the safe condition (for ventilation, humidity control and similar). It results in minimisation of the carbon and environmental footprints. In addition, the closed disposal facility will have appearance similar to a natural landscape and will not make a negative visual impact.

1.5. Knowledge and memory preservation

The reactors were built and operated by foreign military forces of a country, which does not exist anymore. Smooth transfer of design and operation details has not been assured. However, over the past decades, Estonian specialists have been able to gain significant knowledge of the situation through the implementation of a number of international projects. Loss of competence and knowledge is possible due to natural change and aging of staff or reorganizing existing institutional structures. Early waste disposal is preferred because it is difficult guarantee the preservation of knowledge and transfer for several generations.

1.6. Economic factors

Evaluating economic factors is quite a difficult task because it is necessary to compare the costs that will be incurred over a very long period of time. Forecasting future inflation and wage changes is practically impossible for such a long time period, so comparing costs would be incorrect. Therefore, only current costs were taken into account without adjustment for possible inflation and possible price change.

The cost of disposing of radioactive waste will be lower in relative terms (not adjusted for inflation) in 2100 compared to 2040. This reduction is influenced by the following factors: a reduction in the amount of waste due to the decay of radionuclides (larger amount of waste could be suitable for management as non-radioactive waste) and simplification of used equipment. During the extended storage of waste, the process of decay of radionuclides will take place. This will affect the amount of waste required for disposal, as some of the waste may be reconsidered as non-radioactive (below clearance or reuse and recycling levels). The amount of waste for intermediate depth disposal is determined exclusively by the presence of long-lived radionuclides and therefore will not change, or the change will be insignificant. However, the amount of waste in the NSDF, and at the same time the disposal cost, would decrease somewhat.

1.6.1. Scenario A: Reactor dismantling in 2100 with subsequent waste disposal

The main scenario studied was reactor decommissioning in 2100 followed by waste disposal. Taking into account the effect of radionuclide decay on the amount of metallic waste arising from the reactor compartments, in 2040 the most important radionuclides (defining the amount of waste in the NSDF) will be Cs-137, Sr-90, Am-241 and Co-60. After an additional 60 years of decay, the amounts of Cs-137 and Sr-90 will decrease by a factor of 4 and will continue to prevail, while the activity of Co-60 will decrease by more than three orders of magnitude and will lose its importance.

Currently, only rather conservative estimations of radioactive waste inventory is available. A part of available waste is still not characterised, i.e. radionuclide composition is not known. Big uncertainties are associated with predictions of the reactor decommissioning wastes. Therefore, only very rough estimates of reduction of waste amount and consequently the cost are possible. According to the overview of the implementation of the "zero alternative" for the decommissioning of reactor compartments (Sub-activity 5.1), by 2100 the amount of decommissioning waste will decrease by no more than 20%.

In cost estimation of a disposal programme, a distinction between fixed and variable costs should be made. Variable costs are those that vary with the amount of disposed waste while fixed costs remain the same regardless of the amount of disposed waste. The fixed cost must be paid irrespective of the total capacity of waste in the facility. This cost includes: disposal program management, site selection and characterisation, development of technical design, quality assurance, Safety Assessment, Safety Case and Environmental Impact Assessment, equipment for waste characterisation and handling, monitoring, institutional control measures, physical protection measures, offsite infrastructure includes access roads, electrical power and water supplies, telecommunication, on-site transportation routes and connections.

Cost for construction, waste emplacement and closure make up variable costs, nearly proportional to amount of disposed of waste. They include labour costs for waste transportation, handling and disposal, filling the disposal structures, inspection of waste packages, radioactivity monitoring. According to rough estimates considering small size of the disposal facility in Estonia the fixed cost makes up to about 30 to 40% of the NSDF cost. The assumed savings due to a possible reduction in disposal costs may amount to 500 - 600 kEUR.

The cost for the maintenance of the main technological building of the reactor compartments and engineering systems in safe conditions over a period of 50 years is estimated (Sub-activity 5.1) to be up to 34 million euros (on average about 680 kEUR per year). This is about 10 times more than the costs of post-closure institutional control of the disposal facility: the estimated cost of maintenance, surveillance and monitoring of the closed disposal facility amounts to 60-65 kEUR per year. Additionally, 75 million euros will be needed for reconstruction of the Main Technological Building for safe storage of the reactor compartments and radioactive waste.

1.6.2. Scenario B: Reactor dismantling without solution for waste disposal

For some reasons, a decision to dismantle the reactor compartments can be taken without an approved solution for waste disposal. For example, this could potentially happen if it is found that the storage of the reactors are unsafe. In this case a new radioactive waste management facility will be needed. It would include equipment for waste handling and conditioning as well as new a radioactive waste storage facility. It would include an engineered store that is a building, sufficiently shielded, with a solid floor, adequate safety features for inspection of packages and including packaging handling equipment, safety equipment, arrangements to prevent leakage of water, ventilation and temperature control. The construction and equipment of such a storage facility at current prices could cost about 1-1.4 MEUR. The service life of commonly used storage facilities is 50-60 years. Additional costs include the construction of a waste treatment centre (4.4 MEUR) and operating costs, which are 680 kEur per year. From 2040-2100 the total estimated cost could be around 34-41 MEUR. At the end of the storage period, the waste must be disposed of and the waste treatment centre and interim storage need to be decommissioned. Additional earnings are possible through the conversion and reclamation of unused land. Current land plot of PAL site is almost 30 ha. An estimated footprint of the closed disposal facility and area needed to assure physical protection (fences) is about 1.7 ha. Therefore, after decommissioning the reactor compartments and closure of the disposal facility, it will be possible to use the rest of territory (up to about 28 ha) for other purposes. The average forest land hectare price in Estonia ranges between 3 – 10 kEUR [8]. With the right management, the forest and land in Estonia can generate annual profits ranging from 3-10%. Thus, according to present prices the cost of land that will be no longer needed for storage of waste and reactor compartments and potentially can be used for other purposes will make 84 to 280 kEUR in addition to the potential increase in land prices with time.

Therefore, it is evident, that delayed waste disposal has no economic advantage.

1.7. Public acceptancy

The results of the survey conducted in Sub- activity 2.13 show that despite the fact that the Estonian population is not sufficiently informed about the policies and methods of radioactive waste management, and the opinion of the population is quite contradictory, they do not strongly oppose the disposal plan implementation at the Former Paldiski Nuclear Site, but the opposition may appear as the construction of the disposal facility approaches.

On the other hand, the results indicate public opinion that the problem of radioactive waste disposal must be solved in the near future not leaving it to future generations. Therefore, delaying the disposal until 2100 would be against this idea. Finalizing it can be pointed-out that public acceptancy of waste disposal is not investigated sufficiently. It is recommended to look for possibilities to increase public knowledge about safe waste management solutions.

1.8. Conclusions

1. Radioactive waste disposal is the only sustainable solution. It avoids any undue burden on future generations in respect of radioactive waste management. The long-term storage does not eliminate the need for waste disposal after 2100.

2. Long- lived radioactive waste disposal is the safest and most secure long-term option having no alternatives.

3. Updated cost of the disposal project will be 154 million euros. Long term storage (up to 2100) cost will be approximately 109 million euros.

4. Delaying the disposal of radioactive waste has no economic, environmental or social advantages.

2. Sub-activity 3.2. Comparison of alternatives

Characterization of the three candidate sites has been performed during implementation of Activity 2 of the current Project. It included comprehensive geological, hydrogeological, hydrological, geochemical, environmental and social studies, as well as an overview of the available infrastructure. In addition, potential safety implications, including radiological impacts on neighbouring countries, were examined taking into consideration characteristics the sites. The main objective of Sub-activity 3.2 is to compare suitability of the three identified locations and to provide a basis for the strategic assessment of environmental impact of the establishment of the disposal facility and the preparation a designated spatial plan, i.e.to make a decision principle on the disposal site.

The site comparison was performed by Michail Martinkevich and reviewed by Stasys Motiejūnas (UAB EKSORTUS). The detailed results are presented in an Appendix 2.

2.1. Geological conditions

Several sub-activities, namely 2.1 ‘Mapping specific tectonic features’, 2.2 ‘Seismic analysis’, 2.3 ‘Analysis of the geological-lithological composition of the Earth's crust’, 2.5 ‘Analysis of specific geomorphological features’, 2.6 ‘Analysis of hydrogeological conditions’, 2.8 ‘Studies of the chemical composition and properties of groundwater and surface water’ and 2.9 ‘Study of the soil and its deeper layers’, were devoted to studying the geological, tectonic, seismic, hydrogeological and geochemical properties of the three sites. The detailed results are presented in the corresponding Sub-activity reports.

As far as distance between the candidate sites is very small (Figure 1), it was concluded that many characteristics (such as seismic, tectonic, chemical) are nearly identical for all three sites. They are suitable for the disposal facility. However, the PAL site is preferred because the thickest clay-rich unit is at the shallowest depth and the clay-rich interval is the most homogeneous. Also, hydrogeological conditions at ALT site are less suitable for NSDF.

2.2. Environmental conditions

Comprehensive studies of the physical environment included the following sub-activities: 2.4 ‘Analysis and geodetic surveys of surface terrain’, 2.7 ‘Hydrographic studies’, 2.10 ‘Monitoring atmospheric air’, 2.11 ‘Study of climatic conditions’, 2.12 ‘Study of the environment (biota)’ and 2.14. ‘Noise study’. The study results are presented in the Sub-activity reports.

The performed investigations did not reveal any significant negative aspects associated with the PAL site. However, suitability of ALT site for NSDF is compromised because of sea level rise due to potential climate change and complicated water drainage conditions. Therefore, the order of suitability is as follows: PAL, PED, ALT.

2.3. Social environment and availability of infrastructure

Sub-activity 2.13 ‘Study of the social situation’ included investigations of important communities, the purpose of use of the land, land ownership rights, economic aspects, cultural heritage related aspects and other relevant features, while Sub-activity 2.15

'Analysis of roads and infrastructure' is specifying roads and infrastructure at the three selected locations.

The results are detailed in the Sub-activity reports. Rather contradicting results are received comparing different social aspects. PAL site is slightly preferred while other two are nearly equal. Also, the PAL site has the best accessibility and infrastructure. The other two sites are nearly identical.

2.4. Radiation protection and safety

Four Sub-activities are aimed to investigation of safety and potential impacts of ionising radiation: 2.16 'Preparing a safety assessment', 2.17 'Environmental and radiation monitoring', 2.18 'Risk analysis and assessment' and 2.19 'Possible impact of the repository on neighbouring countries'.

Most of safety features are rather similar for all three sites. However, because of the potential inundation risk ALT site is not suitable for NSDF. Additional advantage of PAL site is that there would be no need to transport the waste on public roads. Overall priority is given to PAL site.

2.5. Conclusions

1. Overall conclusion of the comparative analysis of the three potential sites is that the PAL site is the preferable location for the radioactive waste disposal facility. It has obvious advantages over the PED site mainly because of the following features: the shallowest depth of the clay-rich formation suitable for IDDF, small environmental impact, availability of relevant infrastructure and simplest waste transportation.

2. ALT site is not suitable for the radioactive waste disposal facility as safety is not guaranteed and should be excluded from the further comparison.

3. Sub-activity 3.3. Preparing draft technical specification for the specific studies of the repository location

The already performed studies (Sub-activities 1.2 to 2.19) provide a basis for the strategic assessment of environmental impact of the establishment of the disposal facility and the preparation a designated spatial plan. The conducted surveys results are mostly sufficient for further planning and design and fulfill the requirements of the IAEA Specific Safety Guide No SSG-29 'Near Surface Disposal Facilities for Radioactive Waste', although for the technical design more detailed studies are needed. The current report describes the studies needed for the determination of the building rights, preparing the Technical Design of the facility, and applying for a license for the establishment of the repository. During the preparation of the report, it was determined that the following studies are needed: topo-geodetic studies, geotechnical studies and a study of the water drainage network.

The planning was performed by Anna-Helena Purre, Hardi Aosaar and Grete Sabine Sarap (Engineering Bureau STEIGER LLC). Hardi Aosaar and Stasys Motiejūnas (UAB EKSORTUS) reviewed the results. The detailed report is presented in an Appendix 3.

3.1. Geodetic survey

In sub-activity 2.4 "Analysis and geodetic surveys of surface terrain" the surface topography was studied at the Paldiski site. The objectives of the surface topography analysis were to describe the nature and properties of the geological structure of the location and give a topographic overview of the region. The study was done with detail sufficient for safety assessment and spatial planning. For the next stage a more detailed and precise measurements are needed. The purpose of the geodetic study is to prepare a topographic-geodetic base map needed for development of the technical design of the disposal facilities and associated infrastructure.

The topographic/geodetic basic plan shall reflect the relief, the entire above-ground situation and underground utility networks.

As the geotechnical investigations drilling and testing locations coordinates depend on the exact locations of the facilities, therefore it is suggested that the final positioning of the NSDF and IDDF will be fixed by the Contracting authority after the topo-geodetic survey. This is critical to ensure that the next stage geotechnical investigations will be conducted at the right locations.

3.2. Geotechnical investigations

Geotechnical parameters of the site have been described in Sub-activity 2.9 report and the results are sufficient for site selection. However, they are not detailed enough for the next stages (development of Technical Design documentation and the Safety Case). More comprehensive geotechnical investigations are needed to obtain additional data, clarify uncertainties and confirm the geotechnical parameters of the rock mass at the disposal site. The investigation program must be prepared and investigations shall be conducted in accordance with Estonian national regulations.

To ensure the structural integrity of the NSDF and IDDF, geotechnical investigations shall be conducted at their foreseen location. In this phase, the location of the investigation points have not been precisely defined and are herein based on and presented as a general scheme on the generic conceptual lay-out of the disposal area (Report for Sub-activity 2.16). It is recommended that the locations of survey points be adjusted according to the features of the final plot layout, while keeping the number of survey points fixed. Therefore, prior to conducting the geotechnical investigation, the lay-out shall be confirmed by the Contracting authority and the technical designer, considering results of the previous site characterization (water drainage, surface inclination and ground altitude, as well as accessibility) and to be conducted geodetic survey. Additional investigation points may be necessary depending on the dimensions and character of possible service facilities and area if these will be added to the concept in the next stages (for example, access roads and crane rails).

For IDDF geotechnical investigations 1 borehole to the center of the IDDF has been planned (Figure 2). Based on bedrock conditions reported in sub-activities 2.3 and 2.9 and preliminary IDDF design (sub-activity 2.16), the depth of IDDF will be approximately 80 m into the Lontova silt- and claystones. The target depth of the investigation borehole is the upper surface of Kroodi Formation, which based on Sub-activity 2.3 is approximately 126 m from ground surface at the Paldiski site. It is essential to reach Kroodi Formation to determine the possibility of hydrostatic uplift due to water pressure during construction of the facility and emplacement of the radioactive waste.

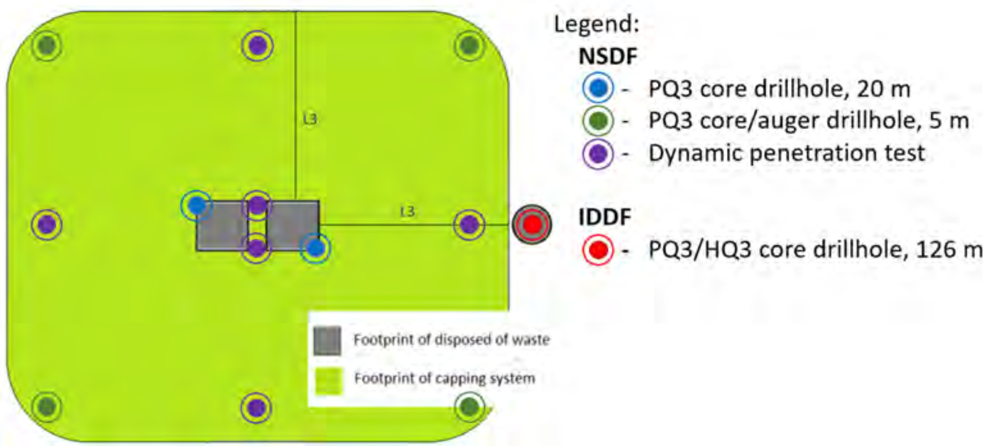

Figure 2. Proposed layout of IDDF and NSDF geotechnical investigation points.

The drilling must be conducted with certified drilling equipment and triple barrel wireline diamond core drilling method to ensure high core recovery with as minimal sample disturbance as possible.

For NSDF geotechnical investigations at least a total of 6 boreholes must be drilled (Figure 2). Two boreholes of 20 m depth must be drilled to the opposing corners of the two concrete vaults and 4 boreholes at each corner of the planned capping system must be drilled until bedrock surface (up to 5 m).

Downhole natural gamma logging must be conducted in the IDDF borehole. Gamma logging shall be conducted after completion of borehole to confirm the depth in terms of lithostratigraphy and geotechnical units as this method allows additional precision with defining different layers, their dimensions and boundaries between layers.

Dynamic penetration testing must be conducted until the surface of bedrock limestone, to obtain in-situ geotechnical parameters for the loose Quaternary soils described in Sub-activity 2.9. As the shingles, gravel and stiff glacial till layers can be hard to penetrate, the Dynamic Probing Super Heavy method is recommended. These tests should be conducted if the Quaternary cover thickness is > 2 m at the repository location.

Water level must be measured after completion of each borehole. Additionally, as some of the aggressivity factors have not been tested during Activity 2 investigations, water samples for aggressivity testing (HCO_3^-, pH, aggressive CO_2, Mg^{2+}, NH_4^+ and SO_4^{2-}) must be collected from nearby survey wells (PAL-101, PAL-201, PAL-401) opening different aquifers relevant to the construction of IDDF.

3.3. Mapping of drainage network

According to Sub-Activity 2.7 ('Hydrographic studies') there is a minor flooding risk at the PAL site. The flooding risk should be mitigated and for that the drainage system, its condition and needed work to improve water flow and reduce the risk of flooding should be mapped on site. The aim of the study is to map the possible drainage network directing the excess water to the sea based on field inventory, determine the needed works and possible mitigation measures.

3.4. The main results and conclusions

1. The results of the studies already carried out are mostly sufficient for further planning of the repository and comply with the IAEA Special Safety Guide No SSG-29 'Near Surface Disposal Facilities for Radioactive Waste', although for the Technical Design more detailed studies are needed.

2. As a result of the performed analysis, the researches needed to determine the construction rights, to prepare the Technical Design and applying for a license for the establishment of the repository were identified and described in details.

3. It was found that the following studies of the site are needed: (i) topo-geodetic investigations to detail the surface features, (ii) geotechnical investigations to obtain detailed information on the physical properties of underlying soil and rocks relevant to design earthworks and structures of the facilities, and (iii) investigation of the water drainage network.

4. The estimated cost of the needed studies is about 183 400 € and the studies would take about 24 weeks.

4. Summary

As a result of Activity 1, "Determining the three most optimal locations for the repository," two possible sites, Altküla (ALT), and Pedase (PED) were selected for the future disposal facility. In addition, Paldiski (PAL), the location of the naval nuclear reactors and the current interim storage of radioactive waste was pre-selected by stakeholders as one potential disposal site.

Selecting the most suitable location for the repository was a goal of the second stage of the project. The selection must be in accordance with the local government designated spatial plan and the related assessment of impact, including the strategic assessment of environmental impact of the repository. By implementing Activity 2 “Studies of the three repository locations” the necessary data were collected that will serve as the basis for the preparation of these documents and making a decision in principle.

The main purpose of Activity 3 was to further study the suitability of previously identified potential sites by conducting a comparative analysis of alternatives, including the “zero” alternative. Another goal of Activity 3 was to outline the future detailed studies of the site in order to get ready to design the repository and preparing the final Safety Assessment Report and Safety Case relevant for a licence application.

According to the approved plan, the reactor compartments will be dismantled in 2040-2050. By that time Estonia should have a radioactive waste disposal facility, which would accommodate waste arising from decommissioning of the reactor compartments. The “zero” option means an alternative to waste disposal, which may be relevant if for some reasons the disposal facility is not constructed and the available radioactive wastes will continue to be stored at the Paldiski site. An analysis of safety, environmental, economic, political and other factors was conducted to evaluate the potential advantages and disadvantages of implementing the "zero" alternative compared to the construction of the disposal facility as planned. The following conclusions were made in the course of the study of the “zero” option:

- Radioactive waste disposal is the only sustainable solution. It avoids any undue burden on future generations in respect of radioactive waste management. The long-term storage does not eliminate the need for waste disposal.
- Long- lived radioactive waste disposal is the safest and most secure long-term option having no alternatives.
- Updated cost of the disposal project will be 154 million euros. Long term storage (up to 2100) cost will be approximately 109 million euros.
- Delaying the disposal of radioactive waste has no economic, environmental or social advantages.

Since there are no obvious benefits to the postponing of waste disposal, it is not reasonable to delay the selection of the disposal site. Characterization of the three candidate sites has been performed in order to compare suitability of the three identified locations and to provide a basis for the strategic assessment of environmental impact of the establishment of the disposal facility and the preparation of a designated spatial plan, i.e.to make a decision principle on the disposal site.

The following recommendations for the strategic assessment of environmental impact of the establishment of the disposal facility are made after scrutinizing all available information:

- ALT site is not suitable for the radioactive waste disposal facility as safety is not guaranteed and should be excluded from the further comparison.
- PAL site is the preferable location for the radioactive waste disposal facility. It has obvious advantages over the PED site mainly because of the following features: the shallowest depth of the clay-rich formation suitable for IDDF, mechanical stability of the rocks (no karstic effects), no inundation risk, small environmental impact, public opinion, availability of relevant infrastructure, simplest waste transportation and lowest disposal cost.

Since the available information about the disposal site is not enough to prepare the Technical Design of the disposal facility and submit an application for a construction license, need for more detailed site characterisation was investigated. The main investigation findings:

- The results of the studies already carried out are mostly sufficient for further planning of the repository and comply with the IAEA Special Safety Guide No SSG-29 'Near Surface Disposal Facilities for Radioactive Waste', although for the Technical Design more detailed studies are needed.
- As a result of the performed analysis, the researches needed to determine the construction rights, to prepare the Technical Design and applying for a license for the establishment of the repository were identified and described in details.
- It was found that the following studies of the site are needed: (i) topo-geodetic investigations to detail the surface features, (ii) geotechnical investigations to obtain detailed information on the physical properties of underlying soil and rocks relevant to design earthworks and structures of the facilities, and (iii) investigation of the water drainage network.
- The estimated cost of the needed studies is about 183 400 € and the studies would take about 24 weeks.