STATE ENTERPRISE RADIOACTIVE WASTE MANAGEMENT AGENCY

SUPPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT REPORT FOR CONSTRUCTION OF A NEAR-SURFACE REPOSITORY FOR RADIOACTIVE WASTE

VERSION 3-2

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STATE ENTERPRISE RADIOACTIVE WASTE MANAGEMENT AGENCY (RATA)

SUPPLEMENTED ENVIRONMENTAL IMPACT ASSESSMENT REPORT FOR CONSTRUCTION OF A NEAR-SURFACE REPOSITORY FOR RADIOACTIVE WASTE

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INTRODUCTION

Lithuania has interim radioactive waste storage facilities that meet safety requirements. However, they are unfit for long term storage of waste. New repositories for permanent storage of waste must be designed and built. We have to do it now, otherwise no Ignalina Nuclear Power Plant decommissioning could be continued, and the existing storage facilities may degrade. Immediate final disposal of radioactive waste allows to save huge costs on interim storage. The final disposal of accumulating short-lived low and intermediate level radioactive waste will not only reduce the Ignalina NPP decommissioning price but will also efficiently improve the human and environment protection, and future generations will not inherit any underserved burden to manage radioactive waste.

In order to implement provisions of the Strategy of Radioactive Waste Management, the Radioactive Waste Management Agency (RATA) has started to prospect for a site suitable for a short-lived low and intermediary level radioactive waste repository. In 2003, Lithuanian scientists helped carry out study *Identification of Candidate Sites for a Near Surface Repository for Radioactive Waste (Identification of Candidate ..., 2004)*. The study identified the key criteria for a repository site (subsection 1.9). They were co-ordinated with the Ministry of Environment, presented and discussed during the international seminar held in Vilnius on 3-4 March 2004. In line with these criteria, several sites have been proposed for further inspection.

International agreements, laws and regulations of the Republic of Lithuania establish legal and environmental restrictions for sites where radioactive waste repositories could be constructed. The site of a near-surface repository must also comply with certain technical characteristics. The location must be safe, it must be free of flooding, erosion, landslides or movements in the Earth’s crust that may damage the integrity vaults, or of any other unfavourable environmental or human threats. The soil must withstand the weight of the repository structures and waste even in case of an earthquake, if any. Moraine, fine sand or gravel is suitable. It is important that packages with radioactive waste are not reached by water in the repository of the selected structure. Precipitation must not accumulate; rather, it must easily flow into a lake or a river. Therefore, it is especially important to provide for and to install precipitation drainage devices. The priority shall be given to the location with a simple structure, with the site that is not expected to change much over time, and with the assessment of the evolution of the system of vaults and their environment being clear and “transparent”. The reliability of the assessment results should not cause any doubts.

The region around the Ignalina NPP is one of the most suitable locations for a near-surface radioactive waste repository in Lithuania. The selection of this region was determined by its close proximity to the nuclear power plant and by rather favourable socioeconomic conditions, such as the low possibility of economic exploitation of the land and the developed infrastructure. The possibility to dispose radioactive waste is significantly restricted by the fact that a large section of the Ignalina NPP territory consists of important protected areas or of areas with the tourist and recreational development potential. However, some areas in the Ignalina NPP territory are neither protected nor attractive for tourism, and they also have soil and geological structure characteristics suitable for a near-surface repository. They could be the site of a near-surface repository.

With due consideration to geological, tectonic and hydrogeological conditions and other criteria determining the safety of the repository, three areas with the most favourable geological and geographical conditions for the construction of a near-surface repository have been singled out in the Ignalina NPP region and conditionally named Dysnos, Zarasai and Visaginas areas (*Identification of Candidate ..., 2004*). According to the initial assessment, the hill in Galilaukė village near the Ignalina NPP, the Stabatiškė site and the Apvardai site have geological, hydrological and topographical characteristics best suited for the construction of a near-surface repository (favourable conditions for surface water run-off, physical and mechanical soil conditions allow forecasting a long-term stability of the slope and a good insulation of compressible water).

The radioactive waste repository must be designed and constructed using high technology and technique. It must be constructed in the location where reference conditions ensuring nuclear safety and radiation protection prescribed by Article 11 of the Joint Convention on the Safety of Spent Fuel and on the Safety of Radioactive Waste Management (*Jungtinė panaudoto ..., 2004*) are secured.

In 2004, the Environmental Impact Assessment Programme for Construction of a Near-Surface Repository for Radioactive Waste (*Paviršinio radioaktyviųjų ..., 2004*) was prepared and approved by Letter No. (1-15)-D8-6022 of the Ministry of Environment on 30 July 2004. Based on this programme and commissioned by the RATA, the Lithuanian Energy Institute and the Institute of Geology and Geography carried out the environmental impact assessment of Apvardai and Galilaukė sites in Rimšė neighbourhood, Ignalina region. Version 4 of the Report dated 14 March 2005 was co-ordinated with all EIA entities and presented to the Ministry of Environment.

At the beginning of 2005, having considered conditions posed by the Ignalina Region Municipal Caouncil, the Lithuanian Nuclear Safety Advisory Committee recommended to investigate additional territorial alternatives. Limited preliminary search investigations were performed in the territory of Visaginas Municipality in April and May of 2005. Three sites in the vicinity of the Ignalina NPP have been selected for the analysis. The largest Stabatiškė site has been recognised as the most suitable. On 11-16 December 2005, at the request of the RATA, the International Atomic Energy Agency (IAEA) organised a mission of international experts that performed an independent assessment of the Programme for Evaluating Sites for Near Surface Disposal. Experts have approved the programme carried out by the RATA (*An international ..., 2006*). The work of this mission has been observed and the analysed sites have been inspected by observers delegated by Latvia and Belarus.

This report has been supplemented by the assessment of another territorial alternative (Stabatiškė site located in the territory of Visaginas Municipality). The assessment of the third site has been performed and the EIA report has been reviewed, amended and issued by VĮ RATA. The supplement has been prepared in consultation with dr. Povilas Ivinskis, dr. Jolanta Rimšaitė, dr. Aleksandras Rimidis, dr. Ričardas Baubinas and dr. Julius Taminskas. Radionuclide migration from the repository via aquatic pathway has been simulated by Jonas Mažeika, *Dr. Hab.*, and dr. Vaidotė Jakimavičiūtė-Maselienė. Geological engineering studies of the site have been carried out by UAB *Grota*.

SUMMARY

The final disposal of short-lived low and intermediate level radioactive waste accumulating in Lithuania will not only reduce the Ignalina Nuclear Power Plant (NPP) decommissioning price but will also efficiently improve the human and environment protection from harmful effect of radioactive materials, and future generations will not inherit any underserved burden to manage radioactive waste. In order to implement provisions of the Strategy of Radioactive Waste Management, the Radioactive Waste Management Agency (RATA) has started to prospect for a site suitable for a short-lived low and intermediary level radioactive waste repository. Lithuanian scientists helped carry out study *Identification of Candidate Sites for a Near Surface Repository for Radioactive Waste (Identification of Candidate ..., 2004)*.

The region around the Ignalina NPP (Fig. S.1.) is one of the most suitable locations for a near-surface radioactive waste repository in Lithuania. The selection of this region was determined by its close proximity to the Ignalina NPP and by rather favourable socioeconomic conditions.

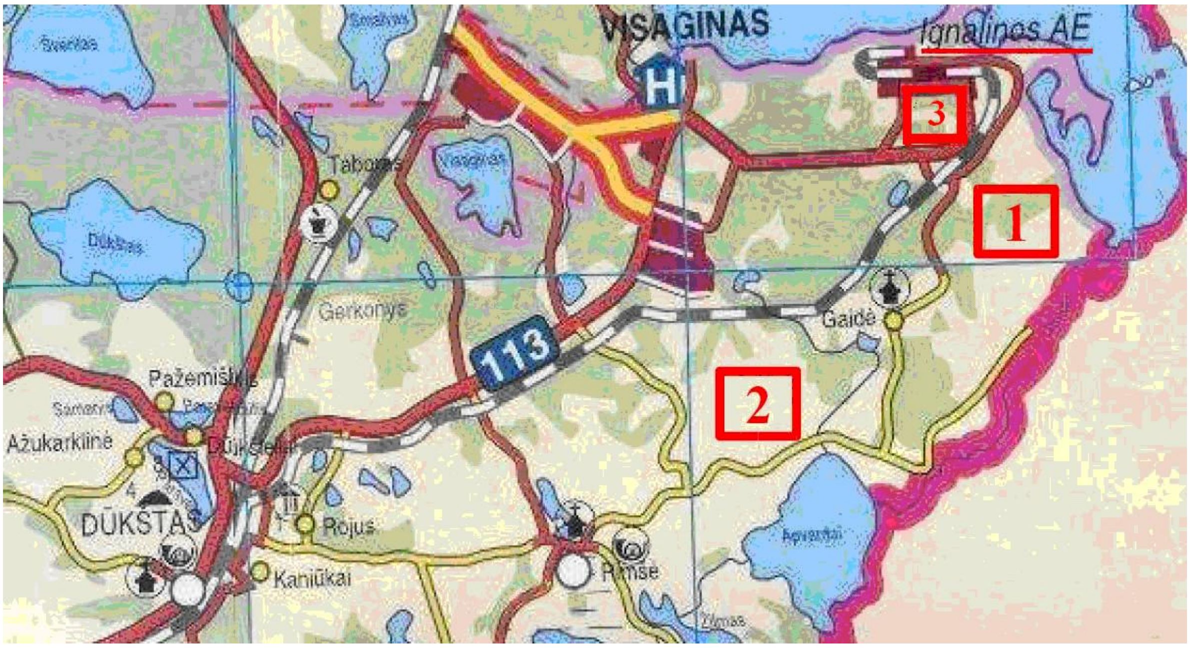

Fig. S.1. Location of Galilaukė (1), Apvardai (2) and Stabatiškė (3) sites in respect of the Ignalina NPP.

This planned economic activity plans to construct a hill-type near-surface repository above the groundwater level in one of the three sites, viz. Galilaukė, Apvardai or Stabatiškė. The conceptual design of the repository is based on the near-surface repository construction feasibility study – the reference design for the construction of the repository – carried out by a Swedish consortium (*Reference Design ..., 2002*).

General data of the proposed near-surface repository and the description of main facilities and technologies are provided in chapters 1 and 2 of the Environmental Impact Assessment (EIA) Report. The conceptual design of the repository has been developed after scrutinizing the design and operational experience of the best existing near-surface repositories all over the world. According to this conceptual design, the repository will have 50 vaults, each designed for the disposal of approximately 2,000 m^3 of radioactive waste. The total volume of the repository would be approximately 100,000 m^3. According to the preliminary evaluation, the repository, its protection zones and auxiliary structures will occupy the area of about 40 ha, including 3 ha of reinforced concrete vaults containing waste. The proposed near-surface repository is of a modular type; therefore, it can be easily adapted to a different amount of radioactive waste by reducing or increasing the number of vaults.

As the disposal of waste will continue for a long time, it is worth while grouping the vaults into individual groups and not buildings all vaults at the same time. Thus, the atmospheric impact on unsealed vaults as well as the maintenance costs of unsealed vaults will be reduced. The repository will be divided into vault groups with due consideration to the expected radioactive waste flow and the characteristics of the site of the future repository. The preliminary evaluation shows that the most optimal solution would be to divide the repository into four groups. At first only one group of vaults will be built and licensed; the remaining groups will be built and licensed later. At the same time the repository may have vaults under construction, operated vaults and sealed vaults. A certain distance must be kept among the vault groups so that different works (construction, operation and sealing) would not interfere with one another. In order to reduce the surveillance time of unsealed vaults, all vaults of the same group must be sealed as soon as disposal is completed. It will allow to reduce the ambient strength of sources of ionising radiation as well as the collective doze and individual doze, also to avoid hazardous atmospheric impact on the vaults and waste packages, and to reduce vault maintenance costs.

The near-surface repository will not have any radioactive waste treatment facilities. Conditioned radioactive waste packages will be delivered to the repository for final disposal. Only solid or solidified short-lived low and intermediate level radioactive waste meeting the eligibility criteria for the disposal of radioactive waste packages will be disposed in the near-surface repository (*Radioaktyviųjų atliekų ..., 2001*). Radioactive waste generated by industrial, medical or scientific enterprises (including spent sealed sources) meeting the eligibility criteria for the disposal in a near-surface repository can also be disposed in the repository. Ineligible and long-lived radioactive waste should be disposed in a deep geological repository of radioactive waste.

The protected territory of the near-surface repository will be divided into the controlled area and the supervised area. The radioactive waste disposal area, an interim storage facility and a facility for service systems and equipment will be located in the controlled area. The administration building and the entrance for vehicles that deliver radioactive waste packages will be located in the supervised areas (Fig. S.2.). The territory of the repository will be fenced; the fence will be located approximately 150 m away from the vaults. The sanitary protection zone shall be established in the area of up to 300 m away from the repository vaults.

Fig. S.2. The conceptual design of the proposed near-surface repository (to be adjusted to the specific layout of the site in the detail design stage): 1 – the entrance and the security check; 2 – the administration, the central control room and the laboratory; 3 – the interim storage facility for radioactive waste packages; 4 – the facility for service systems and equipment; 5 – vaults for the final disposal of radioactive waste and a shelter.

A pilot model of engineering barriers will be built before the commencement of the construction of repository modules. The objective is to demonstrate the functionality and reliability of engineering barriers and to acquire data for safety assessment. The monitoring will last for at least 10 years. The test results will be mostly used for the development of the vault sealing project and during the final safety assessment.

Radioactive waste will be disposed of in the repository approximately until 2030 until the Ignalina NPP will be dismantled and the conditioning of radioactive waste will be finished. The transportation, reception, inspection of the eligibility of radioactive waste packages for disposal and the final disposal of radioactive waste packages will be the principal technological processes during the operation of the repository. The repository zone will consist of vaults. Vaults under operation will be covered by a mobile shelter. The purpose of the shelter is to protect the unsealed vaults, equipment and the zone for unloading radioactive waste packages from direct atmospheric exposure. A remotely-controlled overhead crane performing the transfer of radioactive waste packages will be mounted under the shelter. Lighting, monitoring, etc., systems will be attached to the shelter. When the vault is filled with radioactive waste packages, such vault will be lidded and sealed, while the shelter will be moved to the next vault.

When the disposal of radioactive waste is completed, the repository will be closed by constructing the required engineering barriers. This stage will be carried out according to a detailed repository closure plan. The engineering barriers of the fully constructed near-surface repository will consist of reinforced concrete vaults surrounded all around by low permeable clay, while the whole system will be covered by a long-lived multilayer erosion resistant cap (Fig. S.3.). After the closure, the repository surveillance will be carried out for at least 300 years (*Mažo ir vidutinio ..., 2002*). The organisation operating the repository (RATA) will perform the active surveillance of the repository (for at least 100 years) and will ensure its physical protection, perform the required maintenance of the repository, organise the monitoring of the repository and the surrounding environment, keep records and, if needed, will perform corrective actions. The active surveillance will be replaced by passive surveillance (lasting for at least 200 years). During the passive surveillance, the land utilisation on the repository site will be limited. If required or having received new information, the periods for the surveillance of the closed repository may be extended, while protective barriers may be restored even after 300 years, or waste may be resorted.

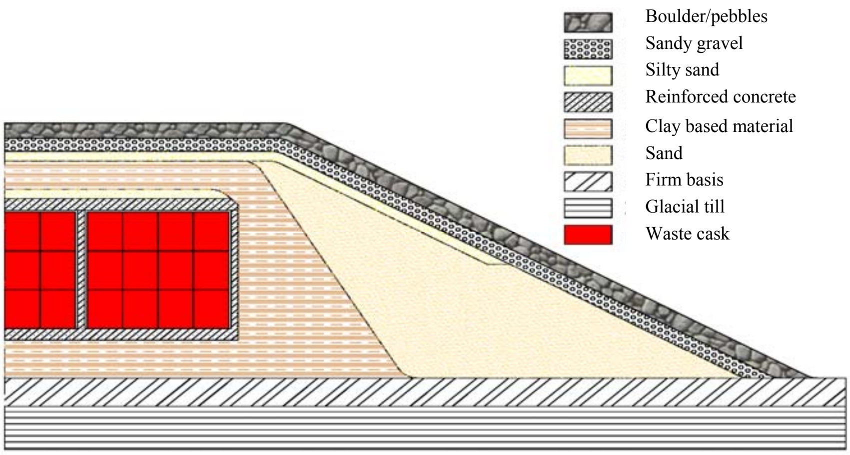

Fig. S.3. Cross-section of the vault after the closure of the repository (*Reference Design ..., 2002*).

With due consideration to proposals received from EIA entities, the concept of the repository has been adapted to the natural characteristics and environmental conditions of the analysed sites. The grass cover was proposed instead of a layer of boulders as provided in the primary concept, and a drainage layer of crushed rock was proposed to be introduced under the vaults (under the clay barrier). The thickness of isolating clay layers will be selected based on the data on natural clay used. During the design process the repository will be divided into vault groups located on the hills based on the relief of the site. The slope inclination will depend upon the characteristics of the soil used for the formation of the slope. A new surface water drainage system will be designed and constructed to improve the run-off of water.

Chapter 3 of the EIA Report describes waste related to the planned economic activity. The construction of the repository is expected to generate only non-radioactive waste. Non-radioactive solid waste generated during the operation of the near-surface repository will be of a household nature. Such waste will be handed over to waste management companies according to waste management regulations (*Atliekų tvarkymo ..., 1999*). The environmental impact shall not be assessed due to a comparatively small amount of such waste. The disposal of liquid non-radioactive household waste shall not be analysed due to small amounts of such waste as well. reference measurements of the specific activity of liquid non-radioactive household waste and rainwater shall be carried out in accordance with applicable provisions of environmental normative documents (*Normatyvinis dokumentas ..., 2000* and *Normatyvinis dokumentas ..., 2001*) and environmental monitoring programme.

As only uncontaminated waste packages are accepted to the repository, no secondary radioactive waste will be generated or only negligible amount of such waste will be generated during the operation of the repository. All generated solid and liquid radioactive waste will be collected according to the applicable radiation protection and radioactive waste management requirements and will be transferred to the Ignalina NPP for conditioning. No radioactive waste will be generated after the completion of the final disposal of radioactive waste, the installation of the cap of the repository and the dismantling of the repository equipment.

Chapter 4 of the EIA Report analyses a possible impact on environmental components and measures reducing this impact. In accordance with the EIA programme, Chapter 4.1 of the EIA Report describes environmental and social conditions in the areas of the planned economic activity and in the vicinity.

The Galilaukė site is in the north-eastern part of Rimšė neighbourhood of Ignalina region, some 4 km to the southeast from the Ignalina NPP and 9 km east of Visaginas. The site is located 0.6 km away from Lake Drūkšiai, 0.7 km west of the Drūkša River and the Lithuanian-Belarus border. The social importance of the site is very low due to the small number of residents and the demographic situation. There is one household in Galilaukė and few settlements in the vicinity. The average number of population in these settlements is a mere 8 residents. The economic importance of the area is also very low, as it is used for extensive subsistence farming. The recreational importance is also very low due to the lack of conditions and resources. There are no other important natural resources in the territory.

The Apvardai site is in the eastern part of Rimšė neighbourhood of Ignalina region, some 8 km southwest of the Ignalina NPP, 6 km southeast of Visaginas, 1.3 km northwest of Lake Apvardai, and some 3 km from the state border with Belarus running along Lake Apvardai. The social importance of the site is very low due to the small number of residents and the demographic situation. There are no residents or households in the Apvardai site, and very few small settlements in the vicinity. The economic importance of the area is also very low, as it is used for extensive subsistence farming and forest-plant cultivation. In the long-term outlook the forest development would only have a local importance. The recreational importance of the area is very insignificant, as the development of recreation and related businesses is mostly limited by the lack of suitable water bodies in the vicinity. There are no other important natural resources in the territory.

The Stabatiškė site is in the territory of the Ignalina NPP, in the eastern part of Visaginas neighbourhood, some 1 km southeast of the Ignalina NPP and some 7 km east of Visaginas. The site is 2 km away from Lake Drūkšiai and some 4 km away from the Lithuanian-Belarus state border. There are some 9 km to the state border with Latvia. The territory is of a little social importance, as it has no residents. The nearest settlements of Marijonavas, Vilkaragis and Skryteliai are approximately 1.5 km away. The economic importance is low. The site is in the territory of the Ignalina NPP and it is not the site of any intensive economic activity except for power engineering. There are no recreational resources or any other resources favourable for the development of organic farming.

Chapter 4.1 presents the results of geological, hydrological and hydrogeological investigation. In order to obtain data required for the final safety assessment and pertaining to a longer period of time, after the hydrological investigations are carried out during the selection of a suitable site, the monitoring of groundwater level will be continued, i.e. the monitoring of the water system will be performed until the commencement of the construction of the repository. Prior to the commencement of the design of the repository the hydrological conditions of the site shall be analysed again with due consideration to the potential impact of new objects under construction in the vicinity on the hydrological conditions of the repository site.

Chapter 4.2 analyses the potential non-radiational impact on environmental and social components of the environment of the near-surface repository, and presents measures reducing this impact.

The analysis of the potential impact on water allows to note that the construction of the repository and the final disposal and storage of waste will have no material impact on water and ambient air, as the facility is not large and no hazardous materials will be used there. Any impact on water may only be caused by an accidental release of fuel or lubricants in the construction site or on roads or by a small amount of domestic effluents. Preventive measures against the release of pollutants into the air or water bodies are proposed, and run-off wastewater collection and control system will be constructed. The quality of released effluents will be monitored.

The analysis of the potential impact on the relief and the soil shows that a regular operation of the near-surface repository will not cause any significant impact. The analysis of the potential changes in the geological environment reveals that the level of water may have to be lowered in all three sites. However, such lowering shall not be significant and will not have any impact on the groundwater regime in the vicinity. During the construction no intensification of geological processes is expected.

The analysis of the biodiversity allows to conclude that the proposed sites for the construction of the repository and the natural area of the repository are not the site of the concentration, feeding, resting, hibernation or migration of fauna. Protected amphibia can be found in the Stabatiškė site; therefore, measures for their protection have been proposed. No preventive measures are applicable in other sites.

The analysis of the potential environmental impact shows that there the proposed sites offer no exceptional landscape values that should be protected. Therefore, from the ecological point of view the local transformation of the landscape in the site area will not cause any negative impact on the landscape complex in the vicinity.

There are no protected territories in the neighbourhood of the sites. The construction and operation of the Galilaukė repository may have a certain negative impact on the ecosystem of the Drūkša river. However, this impact will be basically limited to the noise that scares off the birds. To minimise this impact, the operation of more silent equipment is proposed, and, if possible, construction and digging works should be concentrated in the western area of the site, i.e. further away from the Drūkša river and Lake Drūkšiai. The territory between the repository and the Drūkša river may be afforested.

The impact of the planned economic activity on the socioeconomic environment is based on the economic analysis of the planned economic activity. Due to the geographical location of the existing settlements and demographic trends, the impact on the settlement system should be assessed as insignificant. The impact on the real estate market and prices is insignificant, as the market is inactive, the real estate (land) is either not used or the use is not intensive at all. Conditions for other economic activities would improve as a result to the improved access. The operation of the repository is not expected to have any impact on the economic structure in the vicinity of the repository, as the farming in the territory is not intensive at all, while the number of residents and the demographic structure does not allow to expect any significant positive changes in future. The construction and operation of the repository will not worsen the quality and accessibility of local natural resources, as there are no valuable natural resources in the vicinity of potential repository sites, while the value of the existing agricultural resources is very low. The implementation of the project would create new jobs. This should be regarded as a positive impact for the region where the unemployment level is one of the highest. In the long range the quality of life of the surrounding population would improve as a result of the development of infrastructure. To avoid any negative reaction from the local population, the awareness of the population (both permanent residents and visitors) about the planned project and its environmental impact must be increased.

Chapter 4.3 analyses the potential impact of ionising radiation. Radionuclide migration and exposure pathways depend upon the activities carried out in the repository, therefore they will differ during various stages of the evolution of the repository.

Subsection 4.3.1 provides the assessment of the external exposure of the repository personnel and the population under regular operational conditions of the repository. Equivalent dose rates in typical zones of the repository site (for the assessment of the exposure of personnel) and of the sanitary protection zone (for the assessment of the exposure of population) have been calculated with MERCURE and SKYSHINE codes, which is widely-used in many countries of the world. During the operation the repository personnel may be exposed to radiation while performing the following works: the transportation of waste packages from the Ignalina NPP to the repository; the inspection of packages in the repository; the transportation of packages to the final disposal zone; the sealing of vaults containing waste; the building of the clay barrier over the walls of covered and sealed vaults; the formation of the cap over the covered vaults; the construction of new vaults in the repository under operation; the maintenance and repair of equipment. Other handling of radioactive waste packages carried out in the repository will not cause the exposure of personnel, as these operations will be remotely controlled from the central control room located in the supervised area.

According to the Lithuanian hygiene standard (*Higienos norma HN 73:2001, 2002*), the effective dose for personnel should not exceed 100 mSv over the period of five years, while the maximum annual effective doze should not exceed 50 mSv. The calculated external exposure rate of population under regular operational conditions of the repository is very low and does not exceed the radiation protection limits. It has been estimated that drivers would be exposed to the largest individual doses. The calculated annual exposure dose for a driver transporting radioactive waste packages from the Ignalina NPP to the near-surface repository would be 4.5 mSv. The annual external exposure dose for other personnel engaged in the supervised area of the repository may amount to 1-3 mSv. Many of the works could be performed by Category B workers, i.e. the annual effective dose would not exceed 6 mSv. The number of personnel and the occupational exposure will be optimised during the drafting of the detail design of the repository.

The occupational exposure may be reduced by using ionising radiation shielding barriers, remotely controlled equipment, control and instrumentation and ventilation, by rationally distributing radioactive waste packages of different activity in the vaults of the repository, by immediately closing the filled vaults, by installing engineering barriers of the side walls of the filled vaults, and by efficiently planning and organising works. These measures will reduce the dose rates or the exposure time.

For the purpose of the assessment of the external exposure of population, it was assumed that such exposure was caused simultaneously by all possible sources of exposure. Such sources include the vaults of the repository, a radioactive waste package being loaded into the vault and another radioactive waste package being transported to the interim storage facility. The conservatively calculated annual external exposure dose for population does not exceed 0.16 mSv, which is less than the dose constraint of 0.2 mSv (*HN 87:2002, 2003*). It must be emphasised that the external radiation is determined by the nuclides of the shorted-lived ^{60}Co (half-life: 5.27 years). The influence of other nuclides (e.g. ^{137}Cs) is smaller in several orders of magnitude. Before the construction of the repository is completed, the activity of waste will naturally decrease (the amount of ^{60}Co will decrease almost 4 times within 10 years). Thus, the actual dose rate of the ionising radiation will be much lower. The dose rate can easily be further reduced in the repository area by using special measures; if necessary, the dose rate can be reduced by installing shielding barriers.

Subsection 4.3.2 assesses the exposure of population due to the radionuclide migration via aquatic pathway after the closure of the repository. While assessing the quality of engineering barriers, Roland Pusch demonstrated (*Selection of ..., 2005*) that the selected barriers were very reliable and that it will take several centuries (some 300 years) for water to permeate into the vaults of the repository, given the conditions of Lithuania. Therefore, the carrying of radionuclides from the repository to the environment by water will not be possible for approximately 300 years. However, during the assessment it was conservatively assumed that the repository was already saturated at the time of the closure and that the carrying of radionuclides started immediately afterwards. Thus, it was assumed that the repository was flooded and that the functioning of engineering barriers was inefficient. This assumption allows to assess geological, hydrogeological and hydrological conditions of the sites and to compare them in respect of radionuclide migration.

The analysed *normal evolution* scenario of the repository shows the likely evolution of the repository, including the degradation of the repository expected to occur in the long-term outlook. The following two biosphere models specific to the selected sites have been used for the assessment of the exposure of population:

- *Well model*, assuming that radionuclide releases to water pathway are carried to the well of drinking water used by the population and installed next to the fence of the repository;
- *Lake model*, assuming radionuclide releases to water pathway are carried to the nearest lake the water of which is used by the local population for household purposes, fishing, etc.

The potential radionuclide migration and the resulting exposure has been estimated with widely used DUST, GWSCREEN and AMBER codes. The annual effective doses conservatively estimated for all radionuclides reaching the biosphere under the *normal evolution* scenario shall not exceed:

- 4.1×10^{-4} mSv for the Galilaukė site (Well model);
- 9×10^{-3} mSv (Well model) and 6.2×10^{-4} mSv (Lake model) for the Apvardai site;
- 1.5×10^{-3} mSv (Well model) and 9×10^{-3} mSv (Lake model) for the Stabatiškė site.

The estimated annual effective dose for the Galilaukė site, the Apvardai site and the Stabatiškė site is less than the annual dose constraint of 0.2 mSv. The above estimations have been performed by making conservative assumptions and by applying conservative parameters. Therefore, the likely population exposure doses will be much lower.

Chapter 5 of the EIA Report presents the analysis of alternatives for the planned economic activity. The so-called “zero” alternative (short-lived low and intermediate level radioactive waste is stored in interim storage facilities rather than being disposed) has been analysed. During the analysis of the “zero” alternative it must be first of all stated that in the nearest future the safety of solid radioactive waste storage facilities in the Ignalina NPP will become insufficient. The storage of the existing radioactive waste will have to be reorganised. The decommissioning of the Ignalina NPP will also generate waste; thus, new storage facilities will have to be constructed for the storage of decommissioning waste. Therefore, the delay of the construction of the repository is economically unjustifiable: the failure to construct a near-surface repository may result in approximately LTL 100 million of additional costs for the storage of radioactive waste in 2011-2030. Waste stored in storage facilities will nevertheless have to be disposed in a repository.

Having summarised data on alternative sites, a conclusion is drawn that all three analysed sites are basically suitable for the construction of a near-surface repository; they all meet the safety criteria. The Apvardai site is characterised by complicated social environment and not very favourable geological and hydrogeological conditions. Therefore, this site is rejected. The Galilaukė site has favourable natural conditions and surroundings. However, this site is located in close proximity to the Belarusian border. The natural conditions of the Stabatiškė site are not very favourable for construction. Some unfavourable factors will have to be compensated by additional engineering measures, first of all – by installing the water drainage system. The obvious advantage of the Stabatiškė site is the existing infrastructure, favourable social conditions and a very close proximity to the nuclear power plant. As the site is near the producer of waste, some of the waste acceptance procedures could be optimised and certain auxiliary structures may not be required. The Stabatiškė site is in the so-called “nuclear” territory used by the Ignalina NPP. Furthermore, it is further away from the state border. Therefore, the Stabatiškė and the Galilaukė sites should be further considered as potential alternatives.

Chapter 6 of the EIA Report presents the monitoring programme. The general part of the monitoring programme states the goals of the systematic environmental monitoring, the organisational principles and the regulatory provisions. The programme defines meteorological and hydrological monitoring expected to be carried out in the repository area the results of which are important for the analysis of radionuclide migration in the repository area, the assessment of the exposure of population and for the verification of the compliance of the repository safety with design requirements. The results of such monitoring will also be used for the implementation of the emergency measures and measures for the handling of extreme situations. Chapters 6.3 and 6.4 provide more detailed information about the number and location of monitoring stations required for environmental monitoring, also the sampling and measuring frequency, measured parameters, and measuring means and methods. The quantity and activity of process water and run-off rainwater are expected to be monitored. Soil, grass, groundwater, surface water, aquatic plants, sediments and fish will be tested. The gamma exposure dose rate will be monitored by direct measurements and the absorbed dose will be controlled. Monitoring wells will be built near the vaults of the repository in order to monitor the condition of engineering barriers of the repository (the discharge of radionuclides from the repository). The monitoring programme also describes the quality assurance system, the collection and presentation of data.

Chapter 7 of the EIA Report analyses emergency situations. The design, construction and termination of operation of the near-surface repository will minimise the probability of emergency situations having significant environmental impact from the radiation protection viewpoint. Emergency situations that are likely to occur during the waste disposal stage are related to the handling of radioactive waste, i.e. the transportation of radioactive waste packages to and within the repository, interim storage, transfer and final disposal of packages, operation and maintenance of equipment and installations used in the near-surface repository. After the operation of the repository is completed, the handling and final disposal of radioactive waste will cease and emergency situations associated with this activity will no longer occur. During the supervision and further development of the repository, emergency situations in the long-run may result by possible natural phenomena or events caused by human activities that may have an impact on the isolation of radioactive waste from the environment.

Only conditioned radioactive waste packages will be handled in the near-surface repository. The conditioning will assure (*Bendrieji radioaktyviųjų ..., 2003*) the incombustibility of radioactive waste packages. During the detail design process the potential fire load at other objects of the repository will be minimised, and appropriate fire alarm and fire fighting measures will be selected. Organisational measures will minimise the fire threat. Fire, if any, would be local and would be promptly extinguished without causing any significant release of radioactive materials into the environment.

The following emergency situations during the maintenance and subsequent development stages have been analysed in line with the EIA Programme: the flooding of the repository during heavy rainfall or flood, a rapid degradation of engineering barriers, or an inadvertent intrusion into the vaults of the near-surface repository. The selection of the repository sites and the structure of the repository will prevent waste stored in the repository from being flooded during heavy rainfall or flood, if the repository is normally operated and engineering barriers are intact. The report also states that the surface conditions of all three repository sites will ensure a sufficient and stable (in the long range) run-off of the potential maximum precipitation amount, and thus prevent the sites from flooding.

The safety of near-surface repositories is based on the isolation of radioactive materials until their activity falls down (decays) to the level nonhazardous to humans and the environment. Both engineering and natural barriers isolate radioactive materials and restrict their migration from the repository. During the active surveillance of the repository the physical protection of the repository will be secured, maintenance works will be performed, the monitoring of the repository and its surroundings will be carried out, and corrective measures will be taken, if required. During the passive surveillance of the repository the expected degradation of engineering barriers will be assessed by the scenario of the *degradation of engineering barriers* analysed in this report. Restrictions of activities in the territory of the repository effective during this stage of control must be sufficient to preserve the integrity and the design characteristics of the cap of the repository. When the control of the repository ends, economic activity or land utilisation at the site of the repository will no longer be prohibited or otherwise restricted. Therefore, the scenario of the *degradation of engineering barriers* analysed in this report assumed that all engineering barriers fully degrade and no longer prevent the radionuclide migration upon the expiration of the repository control period. The above results of the scenario of the *degradation of engineering barriers* demonstrate that the calculated annual effective dose per resident is lower for all three sites than the annual dose constraint of 0.2 mSv.

Inadvertent intrusion into the vaults of near-surface repository is possible when economic activity or land utilisation at the site of the repository will no longer be prohibited or otherwise restricted upon the expiration of the repository control period.

Chapter 8 of the EIA Report assesses the possible transboundary impact. The impact is assessed for two states situated relatively a short distance away from the area of planned economic activities, viz. the Republic of Belarus and the Republic of Latvia. Other neighbouring countries are located several hundred kilometres away from the area of planned economic activities. The planned economic activity will not affect these countries.

Chapter 4.2 assessed that the non-radiational impact on environmental and social components of the near-surface repository will either be non-existent or will be minimal and manifesting only in the area closest to the repository. There will be no non-radiational effects on environmental and social components of the Republic of Belarus and the Republic of Latvia.

Whilst analysing the possible effects or ionising radiation on the population of neighbouring states, the exposure resulting from the operation of the near-surface repository were compared with dose constraint applicable to exempted practice. In accordance with international standards of radiation safety (*Basic Safety ..., 1996; International Basic ..., 1996*), an activity is not to be controlled if the effective dose accumulated by any resident as a result of this activity does not exceed 1×10^{-2} mSv/year.

The highest exposure of population of neighbouring states during normal operation of the repository is expected if the repository is constructed in the Galilaukė site. In this case the vaults of the repository would be located closest to the Lithuanian border. For the purpose of the assessment of the exposure of residents of neighbouring countries to direct ionising radiation resulting from regular operation of the repository it was assumed that the external exposure of the population is caused simultaneously by all possible sources of exposure. Such sources include the vaults of the repository, a radioactive waste package being loaded into the vault and another radioactive waste package being transported to the interim storage facility. If the repository is constructed in the Galilaukė site, the calculated effective annual dose on the territory of Belarus is 8.7×10^{-3} mSv. The exposure of residents of Belarus is lower that the dose constraint applicable to exempted activities. It must be noted that the presented calculations do not take into consideration the reduction of exposure when residents stay indoors. The assessment of the activity of disposed radioactive waste was also conservative. Therefore, the actual exposure of residents of Belarus would be lower than calculated. The potential exposure of residents of Belarus or Latvia will be even less if the repository is constructed in either the Apvardai site or the Stabatiškė site, as in this case the distance between the vaults of the repository to the state border is greater than in the above case.

The analysis of emergency situations shows that the worst situation may occur if a radioactive waste package crashes and falls apart in the vault area. The calculation proves that the exposure of residents of Belarus resulting from a crashed package will not exceed 2.4×10^{-4} mSv if the repository is constructed in the Galilaukė site. The potential exposure will be at least 10 times lower that the dose constraint applicable to exempted activities. If the repository is constructed in the Apvardai site or the Stabatiškė site, the potential exposure of Belarusian population resulting from the planned repository, as well as the potential exposure of Latvian population would always be lower, and is therefore not estimated in detail.

In the long-range, after the degradation of engineering barriers of the repository, permissible long-lived radionuclide levels contained in short-lived low and intermediary level radioactive waste stored in the repository vaults may be released into groundwater prior to decomposition. If the near-surface repository is constructed in the Galilaukė site, the released long-lived radionuclides may reach the neighbouring states by groundwater. If the near-surface repository is constructed in the Apvardai site, the released long-lived radionuclides would reach Lake Apvardai. Then the radionuclides may flow from Lake Apvardai to the Daugava river via interconnecting surface water bodies. If the near-surface repository is constructed in the Stabatiškė site, the released long-lived radionuclides would reach Lake Drūkšiai by drainage canals. Then the radionuclides may flow from Lake Drūkšiai to the Daugava river via interconnecting surface water bodies.

The analysis of the *normal evolution* scenario shows that the exposure of a member of the critical group in the vicinity of the repository is less than the exemption level. The exposure of population of neighbouring states would be much less and is therefore not analysed.

A potential exposure of population of neighbouring states in case of an early *degradation of engineering barriers* has been assessed separately. If the repository is constructed at the Galilaukė site, the radionuclides emitting from its vaults would be transferred downwards to the first semi-confined-confined aquifer. The latest studies of the proposed site (*Preliminariniai parinktų ..., 2004*) show that the water of the first semi-confined-confined aquifer flows northwards, i.e. not towards Belarus. Therefore, the radionuclides scattered from the repository will not reach the Belarusian territory and will not have any effect on Belarus.

The DUST and GWSCREEN codes were used to calculate the potential scatter of radionuclides to the Republic of Latvia under the scenario of degradation of engineering barriers and the exposure caused by the said scatter, if the repository is constructed at the Galilaukė site. The estimated effective annual dose received by a resident of Latvia from waterborne radionuclides shall not exceed 3.2×10^{-3} mSv. The potential exposure dose of Latvian population is more than 3 times lower than the exemption level.

If the repository is constructed at the Apvardai site, the long-lived radionuclides leached from the facility would enter Lake Apvardai along which the Lithuanian-Belarusian border runs. Calculation provided in Chapter 4.3 of this Report show that the maximum effective annual dose of the critical group of population living in the vicinity of this lake would not exceed 2.5×10^{-2} mSv. The exposure of the Belarusian population would be close to the exemption level.

In the Stabatiškė site, the long-lived radionuclides leached from the repository would enter Lake Drūkšiai. The maximum effective annual dose of the critical group of Belarusian population living in the vicinity of this lake would be close to the exemption level.

The results of the publication (*J. Mažeika and S. Motiejūnas ..., 2002*) were used to assess the potential effects of the scatter of radionuclides on Latvian population, if the repository was to be constructed in either the Apvardai or the Stabatiškė site. Activities of radionuclides in various environmental objects that could be determined by regular operations of the Ignalina NPP were estimated in this publication based on data on radionuclide outflow into Lake Drūkšiai, using the PC CREAM 97 code. Individual effective doses were also calculated for critical groups (fishermen and their family members) in the radionuclide scatter route Lake Drūkšiai – the Prorva – the Drūkša – the Dysna- the Daugava – the Baltic Sea. The amount of radionuclides released to Lake Apvardai has been calculated by the DUST and GWSCREEN codes. As intense water exchange is the characteristic of Lake Apvardai, all radionuclides getting into Lake Apvardai are assumed to reach Lake Drūkšiai. The estimated effective annual dose received by a resident of Latvia from waterborne (Lake Apvardai – the Daugava) radionuclides via aquatic pathway shall not exceed 6×10^{-3} mSv. The potential exposure dose of Latvian population is 100-odd times less than the exemption level.

Considering the potential transboundary impact of ionising radiation, the Galilaukė site and the Stabatiškė site are better suited for the construction of a near-surface radioactive waste repository than the Apvardai site. If the repository is constructed in the Galilaukė site, the potential exposure of population of both neighbouring states would be less than the exemption level (the potential annual effective dose received by population would be less than 1×10^{-2} mSv).

Chapter 9 of the EIA Report reviews the results of public participation and the evaluation of the EIA Report performed by environmental impact assessment entities. The public presentation and discussion of the supplemented EIA Report took place in Visaginas on 7 September 2006. Afterwards, the supplemented EIA Report was submitted for co-ordination to Utena Regional Environmental Protection Department of the Ministry of Environment, the Radiation Protection Centre of the Ministry of Health, Utena Public Health Centre of the Ministry of Health, Utena County Governor’s Administration, Visaginas Municipality, Ignalina Region Municipality, Fire and Rescue Services of Visaginas and for the protection of the Ignalina NPP of the Fire and Rescue Department, Ignalina Fire and Rescue Service of the Fire and Rescue Department, and Utena Territorial Unit of the Department of Protection of Cultural Values. Comments have been provided only by the Radiation Protection Centre, Utena Territorial Unit of the Department of Protection of Cultural Values under the Ministry of Culture, and the Council of Ignalina Region Municipality. Due consideration was given to these comments.

The Council of Ignalina Region Municipality did not approve the said report on the environmental impact assessment and proposed to analyse the impact on social and economic environment in greater detail as well as to provide for measures to offset such impact. In 2004, the RATA received a similar requirement when it was co-ordinating the EIA report for the Galilaukė and the Apvardai sites; therefore, it commissioned study "Assessment of the Demand for and the Nature of Social Compensatory Measures and the Infrastructure Development in the Area of the Proposed Near-Surface Repository". With due consideration to the potential impact, the study assessed the demand for compensatory measures. The municipal administration of Ignalina Region has been acquainted with the results of the study. As the study provides a detail analysis of potential social and economic impacts that is in line with the Environmental Impact Assessment Programme for Construction of a Near-Surface Repository approved by the Ministry of Environment, the said tests were not repeatedly performed, the more especially as the administration of the closest municipality; viz. Visaginas Municipality, did not raise any similar issues.

According to the provisions of the Espoo Convention, consultations with the neighbouring states were held. In December 2006, the RATA presented the environmental impact assessment results to the public of Latvia and Belarus. Comments received from the neighbouring states are presented in Annex 5. These comments and proposals were thoroughly analysed and evaluated. The proposal to carry out the repository surveillance for more than 300 years and to construct the model of engineering barriers has been accepted. Furthermore, proposals to extend the environmental monitoring to include the territories of the neighbouring states and to intensify the dissemination of information about the waste handling safety have been accepted.

However, the Belarusian proposal to construct a storage facility instead of the planned repository was rejected, as this proposal conflicts with the key provisions of the Joint Convention on the Safety of Spent Fuel and on the Safety of Radioactive waste Management and the fundamental principles of radioactive waste management. As the final disposal of short-lived radioactive waste in near-surface repositories is a common practice, the inheritance of such undeserved burden by future generations would be completely unjustified. Belarus holds that the Stabatiškė site is the safest site of the three for the construction of the repository.

In December 2005, independent experts of the IAEA evaluated the programme under implementation by the RATA. Conclusions and recommendations of experts are presented in the report of the said mission (*An international ..., 2006*). In order to demonstrate the reliability of the repository, the experts and Belarusian authorities proposed to construct a pilot model of engineering barriers and to perform long-term monitoring.

Chapter 10 of the Report describes problems. During the co-ordination of the EIA Report municipalities raised unjustified requirements for compensations. Furthermore, some EIA entities failed to meet deadlines stated by the law; therefore, the process took longer than was expected.

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1. GENERAL DATA

1.1. Information about the organiser of the planned economic activity

The organiser of the planned economic activity is the State Enterprise Radioactive Waste Management Agency (RATA) of Algirdo 31, Vilnius, tel.: 2133139, fax: 2133141, contact person: Stasys Motiejūnas, the Head of the Radioactive Waste Disposal Division.

1.2. Information about the developers of documents of the environmental impact assessment of the planned economic activity

The supplemented environmental impact assessment report has been developed and issued by VĮ RATA of Algirdo 31, Vilnius, tel.: 2104070, fax: 2133141, contact person: Stasys Motiejūnas, the Head of the Radioactive Waste Disposal Division.

The supplement has been prepared in consultation with dr. Povilas Ivinskis, dr. Jolanta Rimšaitė, dr. Aleksandras Rimidis, dr. Ričardas Baubinas and dr. Julius Taminskas. Radionuclide migration from the repository via aquatic pathway has been simulated by Jonas Mažeika, *Dr. Hab.*, dr. Vaidotė Jakimavičiūtė-Maselienė and E. Stonevičius. Geological engineering studies of the site have been carried out by UAB *Grota*. Reference was also made to Version 4 of the EIA Report for Construction of a Near-Surface Repository dated 14 March 2005 and prepared by the Lithuanian Energy Institute and the Institute of Geology and Geography.

1.3. Name of the planned economic activity

The planned economic activity shall be the construction of a near-surface repository for short-lived low and intermediate level radioactive waste (*Radioaktyviųjų atliekų ..., 2001; Mažo ir vidutinio ..., 2002*).

1.4. Activity stages

Pursuant to the resolution of the Government of the Republic of Lithuania (*LR Vyriausybės ..., 2002*), the decommissioning of State Enterprise Ignalina Nuclear Power Plant shall be planned and implemented in accordance with the Immediate Dismantling Strategy. Waste will be disposed of in the repository approximately until 2030 (Table 1.4.1) until the Ignalina NPP will be dismantled and the conditioning of radioactive waste will be finished. Afterwards the repository surveillance will be carried out for at least 300 years (*Mažo ir vidutinio ..., 2002*).

Table 1.4.1. Schedule of construction of the near-surface repository

No.	Stage	Year
1.	The selection of a suitable repository site: geological, hydrological, etc. investigation. Environmental impact assessment of the repository.	2004-2007
2.	The development of the detail design of the near-surface repository.	2007-2008
3.	Construction and licensing of the first group* of repository modules.	2009-2012
4.	Construction and licensing of other repository modules.	As required
5.	Waste disposal (operation of the repository).	2013-2030
6.	Closure of the first group of modules (formation of buffers)	ca. 2018
7.	The termination of operation and complete closure of the repository	ca. 2030
8.	Active surveillance	until 2130**
9.	Passive surveillance	After 2130**

* - with due consideration to the expected flow of waste packages, the repository should be divided into 3 or 4 groups of modules.

** - the optimal duration of surveillance periods shall be established during the development of the repository closure plan.

A pilot model of engineering barriers must be built before the commencement of the construction of repository modules (*Butkus R., Andriuškevičius R., 2006*). The key objective is to make sure of the functionality and reliability of engineering barriers. The expected duration of surveillance is at least 10 years (*Paviršinio kapinyno ..., 2006*). The test results will be mostly used for the preparation for the closure of repository modules and during the final safety assessment.

In order to obtain data over a longer period of time, after the hydrological investigations are carried out during the selection of a suitable site, the monitoring of groundwater and surface water levels will be continued, i.e. the monitoring of the water system will be performed until the commencement of the construction of the repository. Prior to the commencement of the design of the repository the hydrological conditions of the site shall be analysed again with due consideration to the potential impact of new objects under construction in the vicinity on the hydrological conditions of the repository site.

Radioactive waste generated by industrial, medical or scientific institutions (including spent sealed sources) meeting the eligibility criteria for the disposal in a near-surface repository can also be disposed in the repository. Ineligible long-lived radioactive waste should be disposed in a deep geological repository of radioactive waste, and their application possibilities are discussed in the *Assessment Programme of the Possibility of Spent Nuclear Fuel and Long-lived Radioactive Waste Disposal (2003-2007)* (*Panaudoto branduolinio ..., 2003*).

The Law of the Republic of Lithuania on the Management of Radioactive Waste provides that the surveillance of radioactive waste repositories shall be carried out by VĮ RATA. This organisation must be developed so as to be able to ensure a continuing surveillance (for several centuries) of the repository and the storage of information about the repository and disposed waste.

1.5. Expected duration of the economic activity

The design of the repository as well as the construction and licensing of the first group of repository modules (vaults) will last for about 3 years. The disposal of radioactive waste will last for about 20 years; at the same time, other modules of the repository will be constructed. Vaults filled with waste will be immediately closed, thus protected from hazardous atmospheric exposure.

The active post-closure surveillance will be continued for at least 100 years, while the passive – for at least 200 years. During the development of the repository closure plan, the need for the extension of the said surveillance periods will be examined with due consideration to the specific activity of waste disposed in the repository and half-lives of radionuclides significant for radiation protection.

1.6. Relation of the EIA Report with planning and designing stages

The EIA Report is supported by carried out repository construction feasibility studies – the reference design (*Identification of Candidate ..., 2004; Reference Design ..., 2002*). Documents of territorial planning and the detail design of the repository will be developed based on the results and conclusions of this EIA Report. The sanitary protection zone will be established during the development of the detail design of the lot. The safety analysis will be performed at a later stage of project implementation (during the development and licensing of the detail design). Aspects related to the safety of the repository and environmental monitoring must be analysed in detail during the development of the detail design and the final safety analysis report.

1.7. Information about the land area, materials and energy resources required for the construction of the facility

Approximately 100,000 m^3 of conditioned and eligible radioactive waste are expected to be disposed of in the repository. Characteristics and the criteria of eligibility of waste for disposal are more thoroughly described in Chapter 2.1. According to the preliminary evaluation, the repository, its protection zones and auxiliary structures will occupy the area of about 40 ha, including at least 3 ha of repository sections. The size of the repository and the amount of waste to be disposed may be adjusted (approx. ±15%) as needed. The territory of the repository will be fenced; the fence will be located approximately 150 m away from the vaults of the repository. The sanitary protection zone (Annex 2) of about 300 m is proposed to be established around the repository, with due consideration to the results of Chapter 4.3.6. Optimal operational procedures of the repository that would allow to reduce the exposure will be selected during the design stage. Once external exposure is reduced, the boundaries of the sanitary protection zone could be closer than 300 m away from the vaults of the repository.

Electricity will be used during the construction and operation of the repository, vehicle fuel – for the transportation of waste, and electricity or organic fuel – for the heating of the premises. A local substation will be constructed for the supply of electricity. Solid reinforced concrete, concrete, clay, soil, turf, wooden and plastic structural materials, and glass will be used in construction. Information about the key required materials is provided in Table 1.7.1. All these materials are persistent as far as environmental impact is concerned.

Table 1.7.1. Materials required for the construction of the repository; representative quantities

No.	Material	Representative quantity, m^3	Hazardousness of material
1.	Clay	140,000	Non-hazardous
2.	Sand	3,000	Non-hazardous
3.	Silty sand	25,000	Non-hazardous
4.	Gravel	250,000	Non-hazardous
5.	Boulder/pebbles	70,000	Non-hazardous

1.8. Potential environmental pollution related to the planned economic activity

The planned economic activity may cause environmental pollution (Table 1.8.1).

Table 1.8.1 Potential environmental pollution related to the planned economic activity

Pollution	Hypothetical possibility of pollution	Remarks
Ionising radiation	Potential additional ionising radiation: - direct (external) exposure from waste packages during their transportation to the repository; - direct (external) exposure from waste packages during their loading and storage operations; - resulting from the environmental pollution with radionuclides.	Threshold annual dose for population: 1 mSv; Annual dose constraint: 0.2 mSv. Annual background level of ionising radiation: approx. 2.3 mSv.
Non-ionising radiation	No significant pollution of environmental components of this kind is expected during the construction and operation of the facility.	

Noise	No significant pollution of environmental components of this kind is expected during the construction and operation of the facility.	
Biological pollution	Not expected	Low-scale controlled pollution is possible as a result of the release of treated domestic wastewater into the environment.
Other pollution of natural components of the environment	No significant environmental pollution of any other kind is expected during the construction and operation of the facility.	Potential air pollution from mobile sources during the construction and operation of the repository. Insignificant environmental pollution is possible as a result of fuel leakages from vehicles and other machinery as well as in relation to the warehousing of construction materials.

1.9. Candidate territories for the planned economic activity

The selection of candidate territories for the planned economic activity is based on the results of the study carried out in 2003 (*Identification of Candidate ..., 2004*). Criteria for the site of the near-surface repository for short-lived low and intermediate level radioactive waste (*Kriterijai ..., 2003*) have been developed with due consideration to the recommendations of the IAEA, the accumulated international experience and the characteristic features of the concept of a near-surface repository. Table 1.9.1 states the principal technical ineligibility criteria and the desired characteristics of the site. The said criteria were co-ordinated with the Ministry of Environment, presented and discussed during the international seminar held in Vilnius on 3-4 March 2004. In line with these criteria, several sites have been proposed for further inspection.

Table 1.9.1. Principal technical ineligibility criteria and the desired characteristics of the site (*Kriterijai ..., 2003* and *Identification of Candidate ..., 2004*)

Principal site requirements	**Site ineligibility criteria**	**Desired characteristics of the site**
Topographical features	Potential flooding of the foundation of the repository	The surface slope is sufficient for the run-off of rainfall into a water body. A priority will be given to a large hill.
	Low resistance to erosion.	High resistance to erosion: a comparatively flat location, the surface water flow rate v is less than the critical rate v_{kr}.
Geotechnical stability	Unstable slopes (slope stability safety coefficient $F_{\tan\varphi}$ is less than 1.3).	Slope stability (internal friction) safety coefficient is at least 1.5.
	High soil compressibility (high volume compressibility coefficient).	Soil compressibility, compression strength, cutting strength, internal friction angle and rigidity (deformation module) must meet the requirements of substantial structures.

Principal site requirements	Site ineligibility criteria	Desired characteristics of the site
	High dynamic flow ability.	1. Low surplus water pressure of soil pores. 2. The maximum allowable seismic intensity according to the MSK scale is ≤ degree 6.
	Bad conditions for construction.	Digging works can be performed.
	Diversity of soil characteristics.	Homogeneous soil.
Soil permeability	High filtration water permeability of soil (filtration coefficient k is more than 10^{-5} m/s).	Low filtration water permeability of soil. Filtration coefficient k is preferably less than 10^{-7} or even 10^{-9} m/s.
Impact of natural phenomena	1. Unfavourable climatic conditions. 2. Unfavourable hydrological conditions.	1. The average depth of the stratification of groundwater is at least 3 m away from the bottom barrier. 2. Low groundwater level fluctuation amplitude. 3. Hydraulic inclination is less than I = 0.01. 4. No threat of flooding.
Danger related to the transportation of waste	Located far away from the Ignalina NPP; waste is transported via townships, protected or recreational territories.	1. Located close to the Ignalina NPP. 2. Suitable infrastructure; developed road network.

The site of a near-surface repository must also comply with certain technical characteristics. The location must be safe, it must be free of flooding, erosion, landslides or movements in the Earth's crust that may damage the integrity vaults, or of any other unfavourable environmental or human threats. The soil must withstand the weight of the repository structures and waste even in case of an earthquake, if any. Moraine, fine sand or gravel is suitable. It is important that packages with radioactive waste are not reached by water in the repository of the selected structure. Precipitation must not accumulate; rather, it must easily flow into a lake or a river. Therefore, it is especially important to provide for and to install precipitation drainage devices. The priority shall be given to the location with a simple structure, with the site that is not expected to change much over time, and with the assessment of the evolution of the system of vaults and their environment being clear and "transparent", i.e. the reliability of the results should not cause any doubts.. The repository for radioactive waste must be constructed in the location where reference conditions ensuring nuclear safety and radiation protection are secured.

The selection of a repository site may require the assessment of conflicting factors, e.g. a short distance to the nuclear power plant and excellent transportation conditions as well as a short distance to the state border and the request to construct a repository in a retired spot (*Identification of Candidate ..., 2004*). According to the initial assessment, the hill in Galilaukė village near the Ignalina NPP, the Stabatiškė site and the Apvardai site have geological, hydrological and topographical characteristics best suited for the construction of a near-surface repository (favourable conditions for surface water run-off, physical and mechanical soil conditions allow forecasting a long-term stability of the slope and a good insulation of compressible water). The comparative review of the principal aspects of these candidate sites is presented in Table 1.9.2. Site maps and the comparative review of general, environmental, etc., conditions of candidate sites are presented in Chapters 4 and 5.

Table 1.9.2. The comparative review of the principal environmental aspects of candidate sites

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
Information about the existing land use and landholding system	Part of the land is agricultural, the remaining is state forest land (following the recultivation of the construction site).	Agricultural.	State forest land that has the status of Class 3 protective forest. Land user: State Enterprise Ignalina Nuclear Power Plant.
Information about the existing infrastructure	There are no suitable roads, water or power supply equipment in the site. High-tension power transmission lines must be installed and access roads must be built.	There are no suitable roads or water supply equipment. Approx. 1 km long 110 kV power line must be transferred, and access roads must be either reconstructed or built.	The area is circled by roads. The are has a railway, water and power supply equipment. Visaginas Water Treatment Facility is located 1 km away. Domestic wastewater pipeline connecting the Ignalina NPP and the water treatment facility is built near the site.
Situation in respect of protected territories	There are no protected territories in the site and in its neighbourhood. The closest protected territories are protection strips and protection zones of Lake Apvardai and other water bodies.	There are no protected territories in the site and in its neighbourhood. The closest protected territories are protection strips and protection zones of the hydrographical network. The distance to open water bodies (Lake Drūkšiai and the Drūkša river) is 0.5-1 km.	There are no protected territories in the site and in its neighbourhood. The closest protected territories are protection strip and protection zone of Lake Drūkšiai (the distance to the lake is approx. 2 km).
Localisation and surroundings	Located in the territory of Žibakiai village, Rimšė neighbourhood, Ignalina region. The distance from the Ignalina NPP by the shortest road is 9 km, by other roads (the majority of which are not asphalted) – 12 km. The distance to the railway is approx. 2 km. There are alternative routes. Main roads do not cross through townships or protected territories. The frontier zone*.	Located in the territory of Galilaukė village, Rimšė neighbourhood, Ignalina region. The distance between the site and the Ignalina NPP is 4 km, the connecting roads (the majority of which are not asphalted) are approx. 5 km long. The road does not run through townships. There are alternative routes (not asphalted). The distance to the railway is approx. 2 km. The frontier zone*.	Located in the territory of former Stabatiškė village, Visaginas Municipality. The site is in the vicinity of the Ignalina NPP (in its sanitary protection zone). The distance to the railway is approx. 1 km. It is separated from the territory of the Ignalina NPP by a road. The frontier zone*.

* – Frontier zone is a marked strip of land and/or internal waters, extending from the State

border deep into the territory of the Republic of Lithuania, in which the legal regulations of the frontier are in force. It shall be prohibited for persons without personal identity documents to be in the area, where the legal regulations of the frontier are in effect (*Valstybės sienos …, 2000*).

2. MAIN FACILITIES AND TECHNOLOGICAL PROCESSES

2.1. Radioactive waste to be disposed off

The majority of radioactive waste to be disposed off has been generated or will be generated during the operation and decommissioning of the Ignalina NPP. Radioactive waste will first be sorted in accordance with a normative document of the VATESI (*Radioaktyviųjų atliekų ..., 2001*). This document provides the classification and the method of disposal of solid radioactive waste. Radioactive waste is classified into 6 classes (A, B, C, D, E and F). Short-lived low and intermediate level radioactive waste (Classes B and C) and spent sealed sources (Class F) should be disposed in a near-surface repository if waste packages meet the eligibility criteria for the disposal of radioactive waste in a near-surface repository (*Bendrieji radioaktyviųjų ..., 2003*). The RATA will have to control the eligibility of packages. Only radioactive waste packages meeting the eligibility criteria will be disposed off in the near-surface repository.

RATA document (*Mažo ir vidutinio ..., 2003*) establishes the preliminary values of threshold specific activity for grouted short-lived low and intermediate level radioactive waste packages expected to be disposed off in the near-surface repository. These values will be specified with due consideration to information accumulated in the progress of the implementation of a near-surface repository project. Preliminary values of threshold specific activity should be applied during the design of radioactive waste treatment and conditioning facilities.

Only solid or solidified radioactive waste will be disposed off in the near-surface repository. The near-surface repository will not have any radioactive waste treatment facilities, as waste delivered to the repository shall be conditioned and ready to be disposed off. The eligibility of radioactive waste packages for disposal will be additionally inspected in the near-surface repository (*Bendrieji radioaktyviųjų ..., 2003*). The inspection will be carried out in line with the recommendations of the IAEA document (*Inspection and verification ..., 2000*). If radioactive waste packages are eligible for disposal, they will be transported to the disposal area and loaded into the vaults of the near-surface repository.

General eligibility criteria of radioactive waste for disposal in the near-surface repository are described in a normative document (*Bendrieji radioaktyviųjų ..., 2003*). These requirements must be met during the implementation of new radioactive waste treatment technologies. Radioactive waste packages meeting the following requirements regarding chemical, physical, mechanical and thermal characteristics and ionising radiation will be disposed off in the near-surface repository:

1. Radioactive waste packages shall be accepted for disposal in the monolithic form;

2. Radioactive waste packages do not contain any or contain only minimal amount of chemically hazardous or toxic substances;

3. Radioactive waste packages do not contain any pyrophoric substances or substances with the ignition temperature of lower than 60°C. There are no chemical substances or items that may cause explosion. The application of conditioning techniques must ensure that radioactive waste packages are non-flammable. Radioactive waste packages must survive external fire and meet any other established regulations for safe transportation (*Regulations for the Safe ..., 2004*);

4. The description of radioactive waste (the preparation of schedules of packages) will consider the potential formation of explosive gas as a result of the radiolysis of hydrogenic substances, volatile substances present in radioactive waste, or the corrosion of metals (iron, aluminium, etc.). Due consideration will be given to the amounts of organic substances (complexones, cellulose, etc.) present in radioactive waste packages, which will be minimised in order to avoid the decomposition of organic waste. Protective measures will be used in order to prevent the accumulation of flammable and explosive gas in radioactive waste

packages and to prevent any fire or explosion. In order to avoid the bursting of packages, the permeability of solidified radioactive waste and packages must be sufficiently high so as to release gases, yet sufficiently low so as to restrict water migration and the release of radionuclides. The porosity of solidified radioactive waste must be as low as possible so as to improve microstructure and minimise the release of radionuclides (*Bendrieji radioaktyviųjų ..., 2003*).

5. Due consideration will be given to the resistance of radioactive waste packages to corrosion, and proof will be provided that the decomposition of casks and the release of radionuclides into emissions or effluents will not force exposure doses and activity caused by radionuclides to exceed threshold values established in normative legislation.

6. Radioactive waste packages do not contain any or contain a limited amount of reactive substances. Chemically compatible materials shall be used for the manufacturing of radioactive waste packages;

7. During the treatment process solid radioactive waste will be loaded into packages so as to ensure as even distribution of activity as possible.

8. Mechanical resistance of radioactive waste packages to external forces (pressure, tension, bending, dropping and impact) exceed the potential impact during the reloading, storing and disposal of packages.

9. The design of radioactive waste packages will consider the fact that the ambient temperature can be as low as –40°C, and that the cyclic fluctuation of temperatures must neither cause any instability nor significantly decrease the resistance of radioactive waste packages;

10. The radionuclide content of packages should not exceed the established threshold activity values. Threshold activity values will be adjusted during the safety analysis of the near-surface repository;

11. The weight of fissile materials in waste packages shall be restricted so that packages be exempt from regulations applicable to the transportation of fissile materials (*Regulations for the Safe ..., 2004*);

12. The dose rate on the surface of packages and the contamination of packages meet the established regulations (*Bendrieji radioaktyviųjų ..., 2003; Regulations for the Safe ..., 2004*).

Activities of radionuclides contained in radioactive waste packages will have to be measured or evaluated. They should not exceed threshold activity values established according to the methods approved by a normative document (*Bendrieji radioaktyviųjų ..., 2003*). Threshold activity values of each series of radioactive waste packages must be calculated according to dose constraints and threshold dose values for population established by Lithuanian legislation; it is hereby recommended to use the IAEA methods applicable for the inadvertent intrusion scenario (criterion *X*) and the repository evolution scenario (criterion *Y*). Threshold activity values in packages $C_{i,max}$ (inadvertent intrusion scenario) and $A_{i,max}$ (repository evolution scenario) shall be calculated for all significant radionuclides. The following formula shall be used for the calculation of values of criteria *X* and *Y*:

$$X = \sum_i C_i / C_{i,\max} ,$$

$$Y = \sum_i A_i / A_{i,\max} .$$

For radioactive waste packages to be disposed off in the near-surface repository, *X* must be less than 1, while Y should ideally be less than 1. However, a radioactive waste package with $X<1$ and $Y>1$, yet $Y<10$, may be accepted for disposal if the calculation of the average of all packages shows that the average *Y* per package is less than 1, i.e. if the threshold activity of the whole repository is not exceeded. Long-lived alpha emitters shall be subject to an additional requirement, viz. their specific activity should not exceed 4,000 Bq/g in an individual radioactive waste package; however, the calculation of the average of all packages must show the average specific activity of long-lived alpha emitter per package not exceeding 400 Bq/g.

The following radioactive waste generated during the operation and decommissioning of the Ignalina NPP shall be disposed off in the near-surface repository: grouted spent ion-exchange resins, perlites and sediments, ashes from burnt waste, and solid non-flammable waste. Radioactive waste packages must meet the eligibility criteria of for the disposal of radioactive waste in the near-surface repository (*Bendrieji radioaktyviųjų ..., 2003*). According to the plan (*Galutinis Ignalinos ..., 2004*), radioactive waste in the following four forms will be disposed off: grouted waste in 200 l drums, ash pellets compacted by high force compactor in drums, solid waste pellets compacted by high force compactor in drums, and other solid waste.

Grouting facility has already been installed in the Ignalina NPP. Using grouting technology, mixtures of spent ion-exchange resins, perlite and sediments of evaporated concentrate will be solidified. In the grouting facility liquid waste is mixed with cement and promptly distributed into 200 l steel drums. After the mixture hardens, eight drums will be loaded into a concrete cask (*Detailed Design, ... 2004*).

The INPP decommissioning support project B/2/3/4 provides for the construction of the solid waste management and storage facility where operational waste generated on the territory of the power plant as well as similar future operational and decommissioning waste will be sorted, treated, conditioned and temporarily stored. In addition to other functions, this facility will provide the following opportunities: to sort waste according to characteristic activity and physical features, to reduce them in size (to cut, etc.), to compact by high force compactor, to incinerate in the incineration facility, to pack, to immobilise (to fill waste with filler) and to temporarily store waste (*Galutinis Ignalinos ..., 2004*).

Radioactive waste already accumulated in Ignalina NPP will be unloaded from the existing storage facilities and transported to the new facility where they will be described, conditioned, packed and placed from interim storage. Future flammable solid operational and decommissioning waste, also compressible waste and waste to be directly packed and immobilised will also be treated and conditioned in this facility (*Galutinis Ignalinos ..., 2004*).

The exact values of the specific activity of solid and solidified radioactive waste packages to be disposed off in the near-surface repository have not been finalised yet. The major part (approx. 50%) of radioactive waste packages disposed in the near-surface repository shall be grouted packages of spent ion-exchange resins, filtration substance (perlite) and sediments of evaporated concentrate, and these packages will have the highest specific activity. Values of the specific activity of grouted packages of spent ion-exchange resins, filtration substance (perlite) and sediments of evaporated concentrate shall be higher by more than one row (several dozen times more) than values of the specific activity of solid radioactive waste currently stored in the storage facility of the Ignalina NPP and intended for the disposal at the near-surface repository (*Technical Specification ..., 2004*). Therefore, the preliminary calculation of exposure doses conservatively assumes that the specific activity of all waste disposed off in the near-surface repository shall be the same as used in the detail design of the Ignalina NPP liquid radioactive waste grouting facility and interim storage facility as well as in the final safety analysis report (*Detailed Design ..., 2004*), with due consideration to the decrease in the activity as a result of the commencement of operations of the near-surface repository not earlier than in 2011 and the storage of radioactive waste packages in the Ignalina NPP interim storage facility for at least 7 years. The values of the specific activity of the radionuclide content and of the cement matrix (0.2 m^3 drum) of grouted spent ion-exchange resins, filtration substance (perlite) and sediments of evaporated concentrate to be disposed off in the near-surface repository are provided in Table 2.1.1. Values provided in this table were obtained using the methods and procedures developed and implemented by the study carried out by the Ignalina NPP in close co-operation with SIP (Sweden), and they may provide the characteristics of radioactive waste of the Ignalina NPP, which is sufficient enough to assess threats related to their disposal in the near-surface repository (*Detailed Design ..., 2004*). Therefore, these values are used for the calculation of the radionuclide scatter from the closed near-surface repository and the resulting effective doses for a member of the critical group of population following the closure of the repository. Characteristics of all different waste package series must be analysed during the detail design and the assessment of safety.

Table 2.1.1. Average values of the specific activity of the cement matrix (0.2 m^3 drum) of grouted radioactive waste to be disposed off in the near-surface repository (*Detailed Design ..., 2004*)

Nuclide	Specific activity, Bq/m^3
H-3	1,01E+08
C-14	4,73E+09
Mn-54	7,17E+06
Ni-59	3,38E+07
Co-60	1,35E+10
Ni-63	3,86E+09
Sr-90	1,46E+07
Nb-94	5,41E+08
Tc-99	5,95E+04
I-129	5,18E+03
Cs-134	3,26E+08
Cs-137	1,63E+10
U-234	9,60E+01
U-235	2,30E+00
U-238	2,88E+01
Np-237	3,84E+00
Pu-238	1,69E+04
Pu-239	3,07E+04
Pu-240	1,71E+04
Pu-241	3,15E+06
Am-241	6,64E+04

2.2. Conceptual design of the near-surface repository

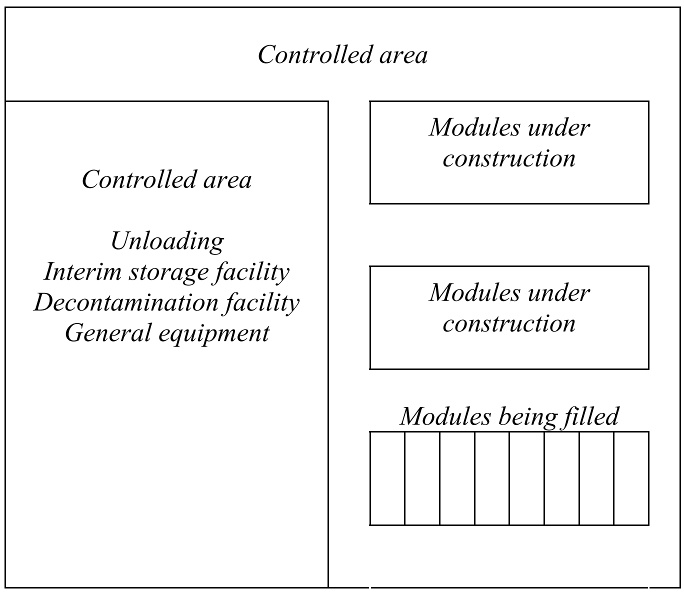
In many countries near-surface repositories for radioactive waste are used for the final disposal of solid and solidified radioactive waste. The experience of several decades shows that it is a realistic, practical and economic waste insulation method allowing to ensure human safety and environmental protection. Both engineering and natural barriers isolate radioactive materials or restrict their migration from the repository. The safety of near-surface repositories is based on the insulation of radioactive waste for a certain period of time. During this period the activity will decrease to the level not threatening human safety and environmental protection.

There are plans (*Reference Design ..., 2002*) to construct a hill-type near-surface repository above the groundwater level. The conceptual design of the repository has been developed after scrutinizing the design and operational experience of the best existing near-surface repositories all over the world. According to this conceptual design, the repository will have 50 vaults, each designed for the disposal of approximately 2,000 m^3 of radioactive waste. Thus, the total volume of the repository would be approximately 100,000 m^3. The structure of the proposed near-surface repository is of a modular type; therefore, it can be easily adapted to a different amount of radioactive waste by reducing or increasing the number of vaults. The size of the vaults will be adjusted during the detail design of the repository with due consideration to the size of radioactive waste packages.

2.3. Main structures and facilities at the site of the near-surface repository

The layout of the territory of the near-surface repository and the auxiliary structures shall be developed with due consideration to the experience in operating similar repositories evaluated and summarised by the technical document of the IAEA (*Technical considerations ..., 2001*). The proposed near-surface repository will have the following most important structures: vaults for the final disposal, the interim storage facility, the facility for service systems and equipment, the laboratory and the administration building (Fig. 2.3.1). The whole protected territory of the near-surface repository will be divided into the controlled area and the supervised area. The radioactive waste disposal area with reinforced concrete vaults, an interim storage facility and a facility for service systems and equipment will be located in the controlled area. The administration building and the entrance for vehicles that deliver radioactive waste packages will be located in the supervised areas.

Fig. 2.3.1. The conceptual design of the proposed near-surface repository (*Reference Design ..., 2002*): 1 – the entrance and the security check; 2 – the administration, the central control room and the laboratory; 3 – the interim storage facility for radioactive waste packages; 4 – the facility for service systems and equipment; 5 – vaults for the final disposal of radioactive waste and a shelter.



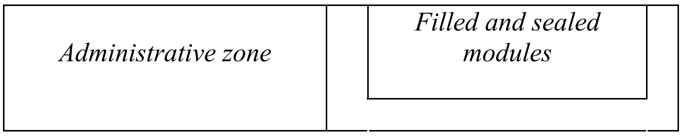


Fig. 2.3.2. Layout of the territory of the near-surface repository (*Technical considerations ..., 2001*).

The administration building will have offices for the administration of the repository, security and service staff of the repository. The building will have the central control room and the laboratory one of the key objectives of which is to perform environmental monitoring (to assess water, and soil contamination, air pollution and plant contamination) and to obtain measurements related to the verification of the eligibility of radioactive waste packages. The required structures, the layout of systems and their attachment to respective zones will be adjusted during the preparation of territorial planning documents and detail design.

The scheme of the reception and transportation of radioactive waste packages in the territory of the repository will be identical to the scheme described by the IAEA document (*Technical considerations ..., 2001*). Upon receiving packages, they will be inspected for their compliance with the eligibility criteria. Afterwards the waste packages will be transported either to the disposal area or to the interim storage facility. Ineligible packages will be returned to the producer of waste. The interim storage facility will have to accommodate the number of waste packages received approximately during one week.

A remotely-controlled overhead crane performing the transfer of radioactive waste packages from one zone to another and the loading of packages in vehicles will be mounted in the interim storage facility. Shielding barriers will separate the package storage area from the area where packages are received and inspected.

Roads in the territory of the near-surface repository joining the radioactive waste packages reception area and the final disposal area will be designed so that the traffic does not interfere with the final disposal operations and does not have any impact on the already filled vaults of the near-surface repository.

The repository zone will consist of modules. The module under operation (the vault into which waste packages are loaded) will be covered by a shelter. The purpose of the shelter is to protect the unsealed vaults, equipment and the zone for unloading radioactive waste packages from direct atmospheric exposure and at the same time to reduce the potential impact (of ionising radiation or in the case of emergency). A remotely-controlled overheat crane controlled from the central control room and performing the transfer of radioactive waste packages will be mounted under the shelter. Lighting, monitoring, etc., systems will be attached to the shelter. When the vault is filled with radioactive waste packages and closed (sealed), the shelter will be moved to the next vault.

Other systems required for the operation of the repository: the site drainage system, power supply system (incl. substation), ventilation system (ventilation system with filters is required for the premises where radioactive waste packages are received and inspected, also for the interim storage facility, premises for the maintenance and repair of equipment and decontamination of vehicles, laboratory premises, and for all other premises where radioactive carry-overs can be generated; ventilation without filters will be installed in other premises), water supply system (a local bore or water distribution system will be installed), wastewater management system (wastewater accumulation, local treatment facilities, or connection to the existing wastewater reservoir allowing to transmit accumulated wastewater to the existing wastewater treatment facility), building heating system (local boiler-room or connection to the existing district heating system), installations for the decontamination of vehicles and equipment, installations for the maintenance and repair of equipment, fire protection system and physical security system.

These and other systems and installations required for the operation of the repository will be described more thoroughly and in greater detail during the development of detail design. It is especially important that the area of the repository remains dry; therefore, a reliable drainage system will be installed, and a special attention will be given to its efficiency (*Rimidis A. ..., 2005*).

During the detail design, the layout of the structures in the repository will be established with due consideration to the site configuration. Considering the specific character of the candidate sites, during the assessment of doses it was preliminary agreed that vaults will be situated in 2 rows, and each row will have 25 vaults. It was also agreed that the absolute altitude of the foundation of vaults will be 150 m in the Galilaukė site and 154 m in the Apvardai site. As a result of a complicated relief of the Stabatiškė site, vaults would be situated on two hills above the groundwater level, in the preliminary altitude of 154 m. and 153.5 m (*Rimidis A. ..., 2006*). During the detail design of the repository, the vaults, the altitudes, the measurements and other parameters will be selected (adjusted) with due consideration to the specific character of engineering barriers and the structure of waste packages as well as to the specified volume of waste.

In order to ensure the physical security of the near-surface repository the whole territory of the repository will be fenced and protection zones will be identified. Special restrictions and requirements shall be established and respective protective technical equipment shall be installed in these zones. According to the initial assessment, the fence surrounding the territory of the repository must be located 150 m away from the vaults, and the sanitary protection zone is recommended to be established in the area of up to 300 m around the repository. The boundaries of the zone have been proposed with due consideration to the results of the estimation of individual dozes described in Chapter 4.3.1. These distances shall be reviewed during the drawing up of territorial planning documents with consideration to the specific characteristics of the locality. The said estimation of doses have been performed by making very conservative assumptions. More information about waste to be disposed off and about the planned repository would allow to make a more realistic assessment and to change the boundaries of the sanitary zone pursuant to the applicable regulations.

Normative documents of the Republic of Lithuania obligate to consider the aggregate impact of ionising radiation of all objects. This will be considered during later stages of project implementation after a more thorough assessment of potential exposure doses. If needed, the detail design may provide for special technical or organisational means to reduce external exposure doses. One of the means to reduce individual or collective doses is to promptly close the vaults of the repository without waiting for the whole repository to be filled with waste.

2.4. Engineering barriers of vaults of the near-surface repository

The engineering barriers of the fully constructed near-surface repository will consist of reinforced concrete vaults surrounded by low permeable clay, while the whole system will be covered by a long-lived multilayer erosion resistant cap (Fig. 2.4.1).

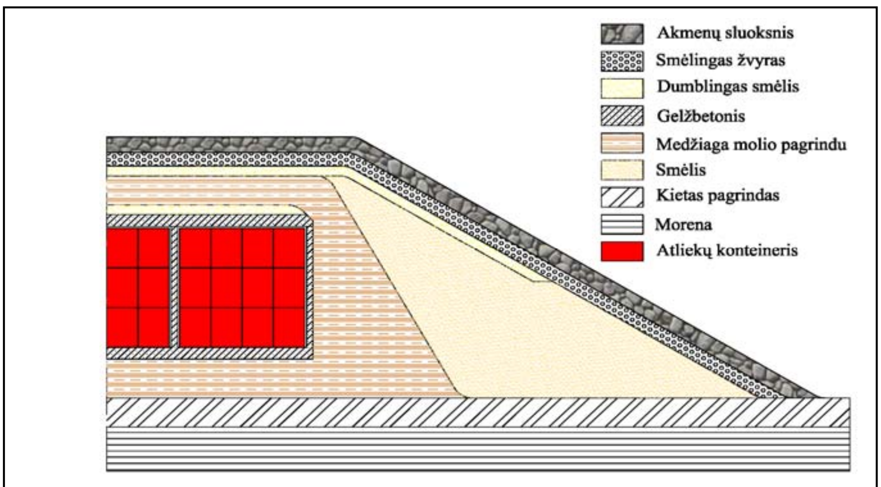


Fig. 2.4.1. Cross-section of the vault after the closure of the repository (*Reference Design ..., 2002*).

Gas may be formed and released during chemical and biological processes under aerobic and anaerobic conditions. Hydrogen will be formed during the corrosion of metals contained in the waste, also during the corrosion of drums and of the reinforcement of packages, while methane will be formed during the decomposition of organic substances. The structure of reinforced concrete vaults must allow the escape of gas released by the waste. The assessment of the release of gas and the potential consequences is provided in Chapter 4.3.3. The assessment of the release of gas and the potential consequences will be reviewed during the detail design of the near-surface repository and the safety analysis report. In order to prevent package disintegration threat, the permeability of solidified radioactive waste and packages will be sufficiently high to release gas (products of chemical and biological processes). Gas will be released from sections of the near-surface repository through the gas permeable joints of reinforced concrete panels covering the vault, without threatening the sections. A thin layer of sand will be poured over the reinforced concrete panels of the vault prior to the construction of a clay barrier in order to ensure an even distribution of gas (*Reference Design ..., 2002*). The escape routes of formed gas will be assessed by the detail design.

Reinforced concrete vaults will be surrounded (from above, all the sides and the bottom) by a low permeable puddled clay (water filtration coefficient $k<10^{-10}$ m/s) barrier (*Reference Design ..., 2002*). Natural smectic Triassic clay found in Northern Lithuania has the required features; tests and investigations of this type of clay have already been carried out (*Jonynas J., 2004, Šačkus V., 2006*). The thickness of clay barriers proposed in the initial version is 1.5 m (*Reference Design ..., 2002*). In order to optimise the structure, thinner insulating clay layers (of 30 and 50 cm as well as 1 m) have been studied, and it has been established that 1 m of clay above and beneath the vault was sufficient enough to insulate the vaults (*Pusch R., 2006; Selection of ..., 2005*). With due consideration to the engineering barrier monitoring results, the thickness of these insulating layers can be adjusted during the detail design. Furthermore, a drainage layer of approximately 1 m in thickness will be constructed under the repository (*Rimidis A., 2005*).

It s proposed to cover the hill with grass. The advantages of such multilayer cover are as follows: in Lithuania, stone is a valuable construction material; therefore, the use of stones for the formation of the surface would increase the possibility of damaging the repository; roots of plants reinforce slopes and protect them from soil erosion caused by wind and water; grass cover accounts for the lesser depth of the frozen soil and therefore for a slower erosion of slopes caused by the freezing and thawing soil; by evaporating much water, grass reduces the possibility of humidity getting into the repository. Grass covered slopes are natural and fitting in the landscape of Lithuania. The detail structure of engineering barriers and specific characteristics will be identified during the detail design of the near-surface repository.

2.5. Technological processes of the construction and operation of the near-surface repository; the system of its surveillance

Earth works shall be the principal works during the construction of the repository. The scope of earth work shall be specified in the detail design documentation. The layout of the vaults and buildings of the repository in a specific site shall depend upon the characteristic features of that site. Vaults may be situated in one long row or in several shorter rows in the repository site (*Reference Design ..., 2002*). As the disposal of waste will continue for a long time, it is worth while grouping the vaults into individual groups and not buildings all vaults at the same time. Thus, the atmospheric impact on unsealed vaults as well as the maintenance costs of unsealed vaults will be reduced. At the same time the repository may have vaults under construction, operated vaults and sealed vaults (Fig. 2.3.2). The repository will be divided into vault groups with due consideration to the expected radioactive waste flow and the characteristics of the site of the future repository. A certain distance shall be kept among the vault groups so that different works (construction and operation) would not interfere with one another. The preliminary evaluation shows that it is expedient to divide the repository into four groups.

The most important technological processes during the operation of the repository shall be the transportation, reception and final disposal of radioactive waste packages. Conditioned radioactive waste packages ready for final disposal shall be delivered to the near-surface repository. Radioactive waste packages meeting the eligibility criteria for the disposal in a near-surface repository shall be transported to the final disposal area where they will be transferred by a crane to the vault for final disposal or deposited at the interim storage facility. Ineligible packages will be returned to the producer for repeated conditioning. Gaps among radioactive waste packages loaded into vaults shall be filled with concrete or sand. The filled vault shall be covered with reinforced concrete. In order for the vault structures and radioactive waste to avoid hazardous atmospheric exposure, the filled vaults shall be immediately reliably sealed. In order to reduce the surveillance time of unsealed vaults, all vaults of the same group must be completely or partially sealed as soon as disposal is completed. It will allow to reduce the ambient strength of ionising radiation as well as the collective doze and individual doze.

During the closure of the repository the vaults will be covered by a protective multilayer cover and a reliable rainwater drainage will be constructed in line with best international practice (*Procedures and ..., 2001*). The closure of the repository will be carried out according to the detail repository closure plan. During the development of this plan the safety assessment shall be reviewed and the procedures and technique of the decontamination and removal or sealing of structures, systems and equipment shall be provided (*Mažo ir vidutinio ..., 2002*). The optimal duration of surveillance periods shall be established during the development of the repository closure plan. During this stage it is very important to develop methods and measures ensuring the safety of data pertaining to the repository. During the surveillance the use of land in the territory of the repository shall be restricted; therefore, it is extremely important to keep information and records.

The organisation operating the repository (RATA) will perform the active surveillance of the near-surface repository and will keep records pertaining to the repository and disposed waste, will ensure the physical protection of the repository, perform the required surveillance of the repository, organise the monitoring of the repository and the surrounding environment and, if needed, will perform corrective actions. The radiation protection will be ensured in conformity with the applicable hygiene standards (*Higienos norma HN 73:2001, 2002; Higienos norma HN 87:2002, 2003*).

After the active surveillance period the passive surveillance shall be carried out. Records pertaining to the repository and waste shall be kept. During the period of passive surveillance the use of land in the territory of the repository shall be restricted (certain types of activities will be banned in the territory of the repository).

If required, protective barriers of the closed repository may be restored or waste may be resorted even after 300 years.

3. WASTE RELATED TO THE PLANNED ECONOMIC ACTIVITY

The construction of the repository is expected to generate only non-radioactive waste. During the operation of the near-surface repository the largest amounts of non-radioactive waste will be generated during operations carried out in the supervised area and in the controlled area. Potential waste shall include construction and demolition (including the building of roads) waste (concrete, bricks, tiles, ceramics, gypsum based materials, timber, glass and plastic), municipal waste and similar commercial, industrial and organisation waste (small metal articles, other metal articles, timber, clothes, textile, green park and garden waste, compostable waste and other municipal waste).

The activity of waste generated in the controlled area will be inspected according to the provisions of environmental normative document LAND 34-2000 (*Normatyvinis dokumentas ..., 2000*). Waste with the specific activity not exceeding the established exemption level will be sorted and transferred to waste management enterprises according to the regulations on waste management (*Atliekų tvarkymo ..., 1999*). The environmental impact shall not be discussed by the present EIA due to a comparatively small amount of waste (the weight is expected to reach 100-200 kg/day). The disposal of liquid non-radioactive household waste shall not be analysed due to small amounts of such waste as well. Reference measurements of specific activity of liquid non-radioactive household waste and rainwater shall be carried out in accordance with provisions of environmental normative document LAND 42-2001 (*Normatyvinis dokumentas ..., 2001*) and environmental monitoring programme (Chapter 6 of this Report).

As only waste packages uncontaminated with radionuclides are accepted to the repository, no secondary waste will be generated or only negligible amount of such waste will be generated during normal operation of the near-surface repository. Potential radioactive waste generated during the operation of the repository may include clothes of the staff, liquid hygiene and cleaning waste, waste from cleaning and decontamination of facilities, waste generated during the repair and maintenance of equipment, etc. If generated, all solid and liquid radioactive waste will have to be collected according to the applicable radiation protection and radioactive waste management requirements and transferred to the Ignalina NPP for management. The domestic transportation of radioactive waste is regulated by the rules approved by Order No. V-834 of the Minister of Health of the Republic of Lithuania on 26 November 2004 (*Radioaktyviųjų medžiagų ..., 2004*). Radiation and other characteristics of such waste will be analogous to waste generated in the Ignalina NPP; therefore, such waste may be treated using the existing facilities of the Ignalina NPP.

The capacities of treatment of the existing or forecasted radioactive waste of the Ignalina NPP will not be increased as a result of the operation of the near-surface repository, as the operation of the repository will only generate a negligible amount of radioactive waste related to staff activities (a small number of staff). The amount of other waste will also be negligible, as the prospective operating facility of the near-surface repository is not complex, performs simple and automated cargo transportation operations, and the number of facilities used is small.

Following the closure of the repository and the construction of the cap all facilities related to the final disposal of radioactive waste packages as well as some of the buildings will become no longer required. If further maintenance of such buildings and facilities will not be expedience from the economic point of view, they will have to be dismantled. After the expiration of the active surveillance period the remaining repository surveillance facilities and buildings will become unnecessary as well. The plan of the decommissioning of the near-surface repository, including the decommissioning EIA, will have to be developed during the operation of the repository. During the development of the decommissioning plan a due consideration will have to be given to the characteristic features of the operation of the repository and to the applicable requirements; therefore, this environmental impact assessment report will not analyse the environmental impact of decommissioning waste.

4. POSSIBLE IMPACT ON ENVIRONMENTAL COMPONENTS AND MEASURES REDUCING THIS IMPACT

4.1 General data on environmental and social conditions

Geographical location of the region and sites

The features of the Ignalina NPP area (in which candidate sites of Apvardai, Galilaukė and Stabatiškė have been identified) have been reviewed in the report on the identification of candidate sites (*Identification ..., 2004*). The following principal geographical features of the region restricting the potential territorial search for sites have been identified:

1. The geographical location of the region is eccentric with regard to the territory of the country, major cities as well as administrative regional centres;

2. The geographical location of the Ignalina NPP (the key source of the radioactive waste) is eccentric with regard to the region: the power plant is in the northeast of the region.

One of the most important peculiarities of the geographical location of the region is the fact that it lies near the border, at the junction of three states (Fig. 4.1.1). The Ignalina NPP, the source of waste to be disposed off, is also situated in the frontier zone, only 5 km away from the state border, on the shore of a transboundary water body (Lake Drūkšiai). The analysed candidate sites are situated near the external border of the European Union.

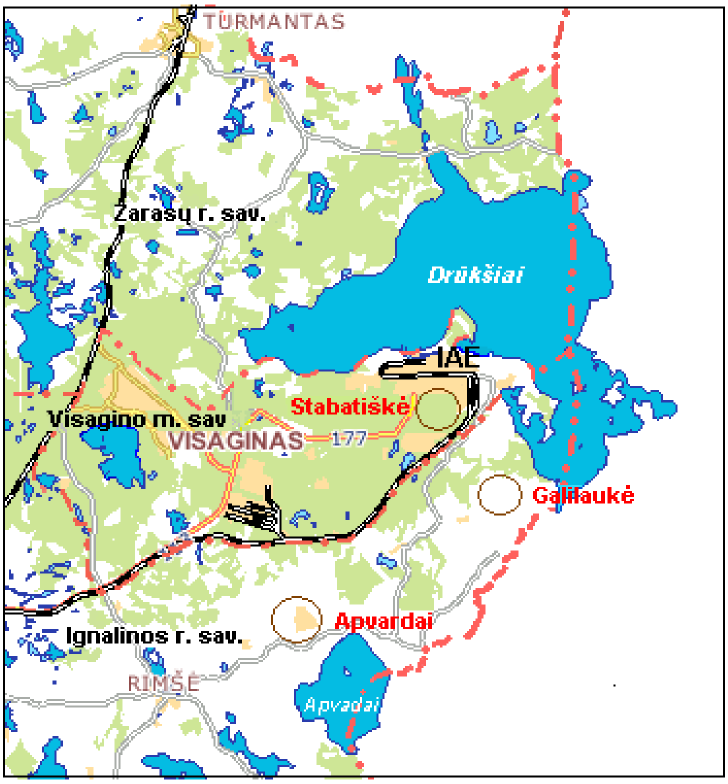


Fig. 4.1.1. Location of Apvardai, Galilaukė and Stabatiškė sites

<u>APVARDAI SITE</u>

The Apvardai site is situated in the eastern part of Rimšė neighbourhood of Ignalina region, some 8 km southwest of the Ignalina NPP, 6 km southeast of Visaginas, 4.5 km east –

northeast of Rimšė, 3.5 km southwest of Gaidė town, among the settlements of Žibakiai, Girdžiūnai, Bieniūnai, Tripuckai and Vigutėnai, 1.3 northwest of Lake Apvardai, and some 3 km away from the state border with Belarus running along Lake Apvardai. The site is located 15.5 km away from the Lithuanian-Latvian border. The distance to the nearest major Belarusian settlements: 6 km to Gireishi and Grituny, and 17 km to Vidzy town.

The distance to the nearest regional road (No. 113, Visaginas-Dūkštas) is approximately 4 km by local roads. There are alternative local automobile routes leading from the nuclear power plant. The site is 4 km northeast of the Pušnis telmathiological reserve.

GALILAUKĖ SITE

The Galilaukė site is in the far north-eastern part of Rimšė neighbourhood of Ignalina region, some 4 km southeast of the Ignalina NPP, 9 km east of Visaginas, 11 km northeast of Rimšė, 2.5 km northeast of Gaidė town, among the settlements of Vosiliškis, Kalnežeris, Mačioniai, Švikščioniai, Varniškiai and Galilaukė. After the boundaries of municipalities of Ignalina region and Visaginas were changed in 2002, the settlement of Kalnežeris was attributed to Visaginas Municipality; therefore, the site is said to be located at the border of two municipalities, viz. Ignalina region and Visaginas.

The site is located 0.6 km away from Lake Drūkšiai, 0.7 km west of the Drūkša River and the Lithuanian-Belarus border. There are no border crossing points in the vicinity of the site. The distance to the nearest major settlements of the Republic of Belarus: 4 km to Drisviaty town, 3-4 km to the settlements of Grituny and Gireishi, 18 km to Vidzy town, and 26 km to Braslav town. The site is located 11.5 km away from the nearest Lithuanian-Latvian border crossing point. There are no major settlements in the Latvian frontier zone.

The distance from the Galilaukė site to the nearest regional road (No. 177, Ignalina NPP-Visaginas) is approximately 3.5 km by local roads There are no alternative local automobile routes (except for field roads) leading from the nuclear power plant.

The distance to the nearest Lithuanian protected territories is 8-10 km. The distance from the planned facility to the Braslav National Park in Belarus established in 1995 is some 20 km.

STABATIŠKĖ SITE

The Stabatiškė site is in the eastern part of Visaginas Municipality, some 1 km southeast of the Ignalina NPP, in the territory used by the Ignalina NPP. Annex 2 describes sanitary protection zones of objects surrounding the site. The site is 7.3 km away from Visaginas and some 1.5 km away from villages of Marijonavas, Vikaragis and Skryteliai. The site is surrounded by automobile roads, and the railway tracks run some 700 m away from the proposed site of the repository. Wastewater treatment facilities and the household waste landfill are located approximately 0.5 km and 1.5 km to the southwest, and the construction waste landfill – some 0.5 km to the south. The wastewater route (used for the delivery of domestic wastewater from the nuclear power plant to treatment facilities) runs adjacent to the site (in the southwest).

The site is 1.5 km away from Lake Drūkšiai and some 4 km away from the Lithuanian-Belarus state border. There are some 9 km to the state border with Latvia.

The distance to the nearest major settlements of the Republic of Belarus: 6.5 km to Drisviaty town, and 7.5-8 km to the settlements of Grituny and Gireishi. The distance to the nearest Lithuanian protected territories is 8-9km. The distance from the planned facility to the Braslav National Park in Belarus established in 1995 is some 20-23 km. The planned repository is over 15 km away from the nearest protected territories in Latvia, the Silene Nature Park and Ilgai and Glushonka Nature Reserves.

COMPARISON OF THE GEOGRAPHICAL LOCATION OF THE SITES

The most significant similarities of the geographical location of the sites:

1. The Galilaukė site and the Apvardai site are in the territory of the same municipality (Ignalina) and the same neighbourhood (Rimšė). The Stabatiškė site is located in the territory of Visaginas Municipality;
2. All three sites are located in the frontier zone;
3. All sites are situated near transboundary water bodies;
4. The sites are further away from larger rural settlements of Rimšė and Gaidė;
5. All sites are close to the railway;
6. All sites are further away from protected territories.

Differences of the geographical location of the sites:

1. Distances from the source of radioactive waste, i.e. the Ignalina NPP, are slightly different. The Stabatiškė site is the closest to the Ignalina NPP.
2. Different access by the existing automobile roads; the Stabatiškė site has the best access.

Socioeconomic importance of the region and the environs of the sites; natural resources

Socioeconomic condition and development of the region has been thoroughly described in earlier studies (*Atominė ..., 1997; Ignalinos AE regiono ilgalaikio ... , 1998; Socialiniai ... , 1999; Ignalinos AE regiono ... , 2002; Identification ... , 2004*; *Ignalinos atominės elektrinės regiono ... , 2004*); therefore, the present EIA report will only present a short assessment of the existing and prospective socioeconomic importance of the region.

The social importance of the region lies in the especially deep contrasts of the social development of the population, viz. the region of the Ignalina NPP may be described as the region of a deep long-term demographic crisis and of the lowest personal income in the country (excluding Visaginas and the nuclear power plant), and at the same time – as the source of the most favourable natural demographic processes and of the highest income level (Visaginas and the nuclear power plant). The preservation of the stability and the introduction of the sustainable development of such a contrasting region may gave a huge impact on social stability of north-eastern Lithuania and maybe on social stability of the whole country. It must be noted that the region is especially important from the multicultural development perspective, as the area of the interface and interaction of different cultures. The fact that the region is characterised by a unique consistent political orientation (described as a separate political geographical region) and is exceptionally important for the political stability (both domestic and international) of the country is also important.

The economic importance of the region is controversial as a result of hardly compatible economic development trends inherited from the Soviet era. On one hand, the region has an especially high energy potential of national (and transnational) importance. On the other hand, the importance of the industry and traditional bioproduction (except forestry) of the region for the national economics is insignificant (the region accounts for only 0.5% of the domestic industrial production, 1-2% of agricultural production, and attracts only 1.4% of material investments). Third, the region is characterised by an exceptionally huge tourism and recreation potential; it has been and still is one of the most important regions of leisure industry in Lithuania that had (and is regaining back) an international importance.

According to the *General Plan of the Territory of the Republic of Lithuania* approved in 2002 (*Lietuvos Respublikos ..., 2002*), the priority perspective functions in the region shall be environmentally-friendly forestry, recreation and conservation. This region is the second functional area (after the seacoast area) where the priority of recreational application of national importance is evident. On the other hand, the *General Plan* recognises that the region will have local areas for the development of industry (in the vicinity of the Ignalina NPP).

The designation of agrarian areas of the region is low and intermediate intensity farming in erosion-sensitive lands. From the resource point of view the priority shall be given to the development of grasslands and to activities alternative to agriculture. The region has favourable conditions for the development of forestry in degrading or relinquished agricultural land. Conditions are also favourable foe the development of hunting, fish farming and apiculture. In the long-run the forestry should be oriented towards a more intense recreational use of forest and protective functions of forest in the region.

The region has peat and clay resources of national importance.

The neighbouring Belarusian frontier zone has a prevailing low-intensity bioproduction with unfavourable development opportunities as a result of low-fertility of lands, the lack of their cultivation and the seclusion of the area. Other directions of economic activities are restricted in the area by the frontier regime.

APVARDAI SITE

The territory is of a little social importance, as a result of the low number of residents and their demographic situation. The economic importance of the area is also very low, as it is used for extensive subsistence farming and forest-plant cultivation following the recultivation. In the long-term outlook the forest development would only have a local resource importance. The recreational importance is also very low due to the lack of conditions and resources. There are no other important natural resources in the territory.

The agrarian importance of the territory may grow in future, as it predominantly has large cultivated meadows and pastures (as well as appurtenances) that are favourable for the development of organic animal husbandry.

GALILAUKĖ SITE

The territory is of a very little social importance, as a result of the low number of residents and their demographic situation. The economic importance of the area is also very low, as it is used for extensive subsistence farming. The recreational importance of the territory is rather low as a result of the lack of conditions and resources; however, the appurtenances are favourable for recreational activities of a local importance). There are no other important natural resources in the territory.

On the other hand, this frontier territory has a local importance for border guard and national defence; therefore, it cannot be abandoned or underdeveloped even if it is insignificant from the socioeconomic point of view.

STABATIŠKĖ SITE

Presently, there are no residents in the Stabatiškė site or in the vicinity. They have been relocated prior to the commencement of the construction of the nuclear power plant.

There are no explored or evaluated mineral deposits in the territory of the site, and the planned economic activity has no impact on the exploitation of other deposits. There are no recreational resources or any other resources favourable for the development of organic farming in the territory, as the territory is heavily anthropogenised. The site could be favourable for forest development as a compensation to technogenic disturbances of the landscape resulting from the construction of the nuclear power plant and the development of its infrastructure.

COMPARISON OF SOCIOECONOMIC AND RESOURCE IMPORTANCE OF THE SITES

Similarities of the sites:

The socioeconomic and resource importance of all the sites is insignificant and microlocal;

All three sites are located in the frontier zone; pursuant to Legal Regulations of the Frontier approved by Resolution No. 598 of the Government of the Republic of Lithuania dated 30 April 2002 (*Pasienio teisinio ..., 2002*), “economic or commercial activities are not restricted in the frontier zone (except in the frontier strip, the state border protection zone and inland waters of the frontier zone).”

Differences of the sites:

The Apvardai site is more favourable for the development of organic bioproduction, and it has a greater potential.

Other industrial or military activities in the vicinity of the sites; surface and air transport; other factors that may have impact on the safety of facilities

In terms of safety, there are no hazardous industrial facilities in the sites or in their vicinity, except for the Ignalina NPP itself. There are no high-pressure pipelines in the vicinity of the sites. The prospective Pabradė-Visaginas gas pipeline will run to the west from the Stabatiškė and Apvardai sites.

There are high-tension power transmission lines near the Apvardai site (to the north); however, they are not related to the security of the object.

The location of the sites is favourable as far as air transport routes are concerned, as there are no permanent air corridors above the sites. The sites are part of the no-flight zone above the Ignalina NPP (within the radius of 5.4 nautical miles). There are no other zones where flights are restricted in the vicinity of the sites. No dangerous (as far as air accidents are concerned) zones have been identified in the vicinity of the sites. The nearest operating military aerodrome is 50 km away near Pastavy in Belarus, and non-operating – near Daugavpils in Latvia (35 km away). The nearest registered civil aerodrome in Lithuania is in Zarasai (28 km away; hardly ever used).

As it has already been mentioned, all three sites are in the frontier zone. This factor is considered to increase the safety of the sites.

4.1.1. Water

General hydrographical situation and hydrological characteristics

The sites under consideration are situated south of Lake Drūkšiai, within its basin. Lake Drūkšiai belongs to the Daugava basin (Lake Drūkšiai → the Prorva →the Drūkša (called the Drisviata in Belarus) → the Dysna → the Daugava → the Riga Bay of the Baltic Sea). The Rychanka, Drūkša (Apvardė), Smalva, Gulbinė and Gulbinėlė rivers and another six nameless streams flow into Lake Drūkšiai (Table 4.1.1.1), and the Prorva river flows out of it (Table 4.1.1.2). The natural annual water exchange (transmissivity) in Lake Drūkšiai is only 29%; however, the large volume of lake water ensures the dilution of the flow.

Prior to 1953 two rivers, the Drūkša and the Prorva, used to flow out of Lake Drūkšiai, and the area of the lake was 466 km². 3.5 km downstream from the end of the lake, the Drūkša joined the Apyvardė flowing out of Lake Apvardai. Downstream from the confluence the river was called the Drūkša or Drisviata; 14 km downstream the Prorva fell into it. The total length of the Drūkša was 48.1 km. During the construction of the city of Visaginas, the city's domestic wastewater was directed to treatment facilities situated at Lake Skripkai. Treated water flows from the said Lake Skripkai to the Gulbinėlė rivulet flowing to Lake Drūkšiai.

Table 4.1.1.1. Characteristics of Lake Drūkšiai

Lake No. (cadastre)	33-7
Area, ha	4,480*
Average depth, m	8.21
Deepest point, m	33.3
Volume of water, thousand m³	367,650
Area of the basin, km²	620 (470**)
Transmissivity, % per year	29
Effluent	Prorva

* 76% (3,700 ha) belongs to Lithuania, while 24% (1,200 ha) – to Belarus. According to the List of State Lakes, 3,204.9 ha are in Zarasai region, and 417 ha – in Ignalina region.
** The area excludes the Apvardė basin.

Table 4.1.1.2. Tributaries and effluent of Lake Drūkšiai

Tributaries and effluent	Length, km	Area of the basin, km²
Rychanka	20.3	213
Apyvardė	11.4**	147
Smalva	11.9	88.3
Gulbinė	8.0	33
Gulbinėlė*	5.9	6.3
Other small tributaries	-	76.4
Prorva (effluent)	-	613

* Treated domestic wastewater of Visaginas city are released into the Gulbinėlė.
** Including 4.4 km of the former bed of the Drūkša.

The area has natural swamps varying in size, the most important including lakeside swamps on the south-western shore of Lake Drūkšiai and the northern shore of Lake Apvardai, as well as riverside swamps along the Apyvardė (Drūkša). The largest swamp areas are located north of Lake Apvardai. Small swamps related to specific sites are described below in respective subsections of this chapter.

The hydrographical network of the basin of Lake Drūkšiai was substantially changed in the 20th C. At around 1912, during the construction of a watermill a canal was excavated between Lake Drūkšiai and Lake Stavokas. Some of the water flowing out of the lake along Lake Stavokas and Lake Obolė started flowing along the new bed straight to the river Drūkša, and the remaining water flowed as the old effluent. After a hydro-electric power plant was constructed downstream from Lake Stavokas in 1953, a sluice was installed for the control of the flow. During the same year the Drūkšta (the Drisvėta, or Drisviata in cadastres) was dammed 50 m downstream from the Apvardė mouth by a 3-metre-high dyke (before the lake was dammed, the Drūkša was an effluent of the lake). The whole flow of Lake Apvardė was thus directed along Lake Drūkšiai and from it – along the new effluent. The 300 kW hydro-electric power plant was decommissioned in 1982; the hydrographical network, however, was not re-naturalised. The Drūkša dam is in Belarusian territory. The state of the dam and operation conditions are not known. If the dam is demolished or naturally falls in decay, water from Lake Drūkšiai will once again start flowing in two directions, i.e. along the Prorva and the Drūkša.

In 1953, a dam was constructed at the confluence of the Drūkša and the Apvardė, and the whole flow of the Apvardė was thus directed to Lake Drūkšiai whose basin as a result grew to 613 km³. The flow direction was changed in the section of the Drūkša between the effluent and the confluence with the Apvardė. As a result, Lake Drūkšiai has a sole effluent, viz. Prorva (in Belarus). At present the average flow of the Prorva flowing out from Lake Drūkšiai is 3.2 m³/s. The Prorva's length from the point of outflow to the confluence with the

Drūkša is 12.3 km. Downstream from the confluence with the former Drūkša the river was bifurcated by man. The Drūkša is the right-bank tributary of the Dysna. The total hydrographical distance from the outflow point from Lake Drūkšiai to the Dysna is 44.5 km. The total length of the Dysna is 173.4 km, and the area of its basin is 8,179.5 km^2. Its average flow at Kazėnai is 10 m^3/s, and as large as 30 m^3/s at Sharkovchizna. Downstream from the confluence with the Drūkša (Drisviata), the Dysna flows for 113.6 km before falling into the Daugava (near the town of Dysna in Belarus), some 425 km from the mouth of the Daugava. The average flow of the Daugava at the mouth of the Dysna is 288 m^3/s, and as large as 451 m^3/s at Daugavpils. In its mouth (the Riga Bay), the flow of the Daugava reaches 700 m^3/s.

The hydrographical distance from the point of outflow from Lake Drūkšiai to the Riga Bay in the Baltic Sea is about 580 km (information is provided in Chapter 8). Given the location of the candidate sites, it can be stated that the hydrographical distance from Galilaukė, Apvardai and Stabatiškė sites to the Baltic Sea is approximately 587 km, 601 km and 591 km, respectively.

Description of land reclamation systems

The hydrographical network of the area has especially been changed by selective (of a comparatively small territories) drained land reclamation. It changed the length and the density of river beds as well as hydrographical dependency of basins, as certain secluded swampy lowlands were joined with natural waterways or lakes. Drained land reclamation was especially intensive in the 70's of the 20th C. We have no more detailed data on the impact of the drained land reclamation on the whole area.

The key results of the drained land reclamation were as follows: beds of small natural rivulets (the Gulbinėlė) were canalled, and secluded swampy lowlands were joined with waterways by canals. As a result, also due to the underground drainage network, the hydrological regime of natural waterways could have been changed in drained areas. The situation of the majority of land reclamation systems is either satisfactory or bad, as there are many unclean canals, and in certain areas (e.g. between Švikščionys and Beržininkai villages) water is accumulating in lowlands as a result of the bad operation of drainage.

Characteristic features of the hydrological regime of the territory

Data of various posts can be used for the hydrological description of the southern side of the basin of Lake Drūkšiai; summarised sources also exist (*Jurgelevičienė ir kt., 1983*). The water measuring station at the point of outflow from Lake Drūkšiai is located in Lake Drūkšiai near the Prorva canal. There are 8 operating water measuring stations in the basin of Lake Drūkšiai, excluding the water measuring station on the Gulbinėlė (*Gailiušis ..., 2001, p. 714*); the latter has not been indicated in this source. However, according to the diagram on page 122 of the same source, the basin of Lake Drūkšiai does not have a single water measuring station of the Lithuanian Hydrometeorological Service. It seems likely that former 8 departmental stations are no longer in operation. At present Lithuania has three departmental stations of the Ignalina NPP, viz. Gulbinė, Gulbinėlė and Object 500 (in the town of Drisviaty in Belarus). According to the data of the Belarusian Hydrometeorological Service, there is one water measuring post on the Belarusian side in the basin of Lake Drūkšiai, i.e. on the Rychanka river. During the construction and operation of the Ignalina NPP, data of 10 posts established in 1926-1976 and operating for different length of periods were used for hydrological research (*Jurgelevičienė ir kt., 1983*).

Based on flow maps (*Resursy ..., 1969*) compiled prior to 1969, the hydro module of the upper reaches of the Dysna is 7.5 $l\ s^{-1}\ km^{-2}$ (Table 4.1.1.3). It is 30% higher than the hydro module of the basin of Lake Drūkšiai calculated over a short period. Till and clay prevail in sites. As a result of the land reclamation system, groundwater inclinations are towards the Apvardė, Lake Drūkšiai and the Gulbinėlė (the Galilaukė site) and towards Lake Apvardai (the Apvardai site). The flow of groundwater is 2-3 l s^{-1} km^{-2} (*Resursy ..., 1969*). As a result of a comparatively continental nature, 45-60% of the surface flow in the area is due to the spring flood (*Jurgelevičienė ir kt., 1983*).

Table 4.1.1.3. Hydrological characteristics of the southern side of the basin of Lake Drūkšiai (according to *Resursy ..., 1969*)

Indicator	Numerical value
Average annual flow, l/s km²	**7.5**
Minimum flow module during the cold period, l/s km²	**3.3**
Minimum flow module during the warm period, l/s km²	**2.5**
Winter flow module, l/s km²	**5.5**
Summer-autumn flow module, l/s km²	**4.7**
Average flow height during the spring flood, mm	**75**
1% probability of the flow height during the spring flood, mm	**137**

As it has been mentioned already, the described area has an increased surface flow as a result of the activities of Visaginas treatment facilities. Treatment facilities are adapted for full biological treatment with an additional treatment using sand filters. The efficiency is up to 300 l s^{-1}. Treated domestic wastewater is released to Lake Drūkšiai via the Gulbinėlė rivulet. As a result, the flow of the Gulbinėlė (the average natural rate of flow is approximately 37 l s^{-1}) may increase several times. On 23 August 2002 the rate of flow of the Gulbinėlė was 103 l s^{-1} (hydro module: 16.3 l s^{-1} km^{-2}), while on 5 July 2004 the rate of flow was 99 l s^{-1} (hydro module: 15.7 l s^{-1} km^{-2}). Meanwhile, on 23 August 2002 the hydro module of the Gulbinė was 19 times lower (0.85 l s^{-1} km^{-2}) than that of the Gulbinėlė. The natural hydro module of these tributaries should be similar (Table 4.1.1.4). Hydrochemical tests of water of the Gulbinėlė demonstrate that treated domestic wastewater of Visaginas does not have biochemical characteristics similar to those of the surface water in the vicinity; treated wastewater has an especially high concentration of phosphorus (Table 4.1.1.10).

Table 4.1.1.4. Flow of the tributaries and effluent of Lake Drūkšiai

Rivulet	Hydro module, l s^{-1} km^{-2}	Percentage of the flow of tributaries in the basin, %
Rychanka	5.0	40
Apyvardė	5.8	24
Smalva	5.8	17
Gulbinė, D-3, D-4	5.8	8
Other small tributaries	4.5	11

Characteristics of water level fluctuation of Lake Drūkšiai

Water level fluctuations of Lake Drūkšiai are especially important for the Galilaukė site. Data of the Lake Drūkšiai water measuring station show that the lake water level fundamentally changed at around 1953 (after the hydro-electric power plant commenced its operation) and at around 1982 (after the decommissioning of the hydro-electric power plant). In 1952-1982 the lake water level was approximately 0.3-0.5 m higher than before and after the specified period (Fig. 4.1.1.1).

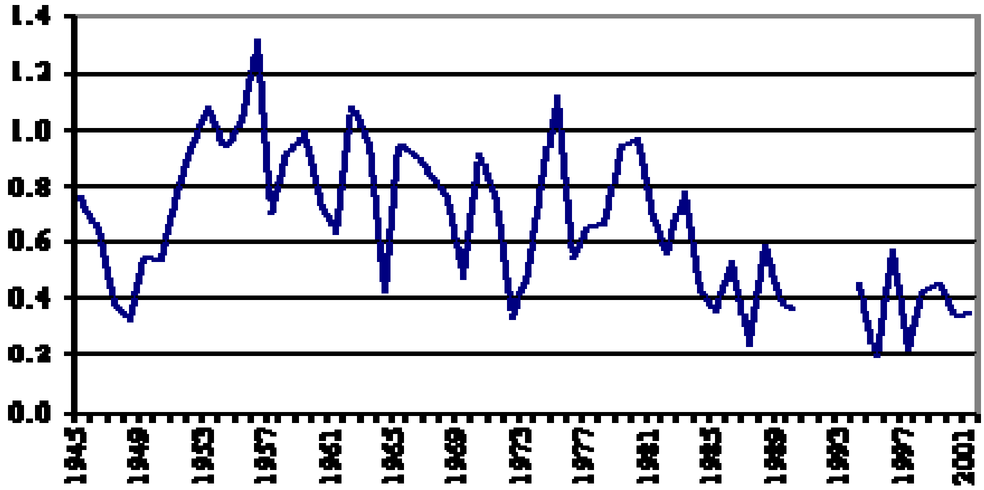


Fig. 4.1.1.1. The amplitude of water level fluctuations of Lake Drūkšiai, m. The height of 0.0 m is equal to the altitude 140.26 m.

According to the previous research data (*Jurgelevičienė ir kt., 1983*), the absolute amplitude of the level of water in Lake Drūkšiai was as big as 150 cm (the average monthly level amplitude is 136 cm). It means that the highest level of the lake could have been 142.35 m of the absolute height. The maximum level is most frequently observed in April. During the operation of the hydro-electric power plant, level fluctuations were periodic. The average duration of the spring flood: 82 days. The average intensity of the rise of the water level: 2.3 cm/day. The rise of water is more intensive than the settlement, therefore the settlement phase takes 2/3 of the flood duration.

After the decommissioning of the "Tautų draugystė" hydro-electric power plant and the commencement of the regulation of the level of Lake Drūkšiai (first of all – for the needs of the Ignalina NPP), the amplitude of fluctuations of the lake level is thought to have been decreased several times (Fig. 4.1.1.1).

Probability of flooding of the territory

This part reviews the probability of floods in the southern part of Lake Drūkšiai. It should be noted that there are no data on any previous floods in this area. Only the spring flooding of riverside and lakeside swamps is common. The probability of floods in the discussed area has been identified during the evaluation of the whole territory of Lithuania regarding floods (*Taminskas, 2002*). Having established qualitative criteria of flooding, it has been stated that the probability of flooding is low. If flooding of the Dysna valley in Ignalina region is eliminated, the probability of flooding in the remaining territory of the region is very low. The area should not be classified as a territory with unfavourable farming conditions due to flooding.

The threat of flooding the area and even the region would emerge if the flow from Lake Drūkšiai along the Prorva would be discontinued for technogenic reasons and if the sluice was of an unlimited height. The probabilities of the fluctuation of water levels in Lake Drūkšiai and the Drūkša-Apyvardė are provided in Table 4.1.1.5. Thus, if the lake water level rises 0.4-0.5 m (to 142 m of the absolute height), the changed direction of the Drūkša (Apyvardė) in the section from Mačioniai village (the former point of outflow) to the area downstream the dam would correspond to the direction before the erection of the dam.

Table 4.1.1.5. The probability of the potentially biggest flooding of Lake Drūkšiai, Lake Apvardai and the Drūkša-Apyvardė river

Probability, %	Drūkšiai	Drūkša-Apyvardė
99	141.28	141.68
95	141.31	141.71
90	141.5	141.85
80	141.59	141.99
70	141.67	142.07
60	141.84	142.24
50	141.90	142.30
40	141.95	142.35
30	142.03	142.43
20	142.10	142.50
10	142.20	142.60
5	142.25	142.65
1	142.27	142.67
<1	143.10	144.00

Local flooding can be caused by other reasons (obstacles in waterways, intense precipitation or melting of snow). The rise of the groundwater is possible only in the nearest area of the damming of surface water; however, it will not exceed the highest altitude of surface water.

The potentially highest rise of the water level in Lake Drūkšiai depends upon the altitude of the upper pool of the sluice on the Prorva, which is presently being specified. In any case, the rise should not exceed 144 m of the absolute height (it is the altitude of the top of the earth dam); however, such rise of the water level of Lake Drūkšiai can already impact the interbasin transfers of surface water including lakes Apvardai, Žilmas, Rūžas, Alksnas and some other lakes in the discussed territory.

The global sea level rise is not relevant for the area, as the absolute height of the sites is 140-180 m: such global sea level rise is not expected for the nearest 300 years.

Information about local conditions of the formation of surface (basic) flow

In order to describe local conditions of the formation of flow it should be noted that the amount of precipitation during the vegetation period differs only by 3% on different slopes of glacial hills; however, the difference of amounts of short-term precipitation can amount to 8-12% or even more in the case of showers (*Gidrologičeskije ..., 1988; Ignatavičienė, 1972; Kaušyla, 1973*). The height of the coat of snow on different slopes of glacial hills differs by 1.7-3.6 times (*Gidrologičeskije ..., 1988*) even though water resources in the snow differ less. This is determined by different thickness of snow. Wind directions prevailing in the region in winter determine larger snow deposits on the top and middle sections of northern and north-eastern slopes of the hill. Convex slopes are characterised by large snow water deposits in the upper sections of the slope, which increases the erosive potential of water generated by the melting snow.

The frost of the soil is an important local factor of the flow formation. Previous studies of the hilly moraine agro-landscape established that in heavy winters the depth of the frost in moraine hills varied from 30 cm in peaty foot of the hill to 90 cm on weather-beaten hilltops. The frost on arable slopes and hilltops is 10-50% deeper than in the area of perennials (*Gidrologičeskije ..., 1988*).

The Institute of Land Reclamation (later renamed to Water Management Institute) of Lithuania had standards for the study of drainage systems, ditches and surface flow installed in a similar physical geographical location not far from the considered territory (near Saldutiškis, north of Lake Žiezdrelis, Utena region). Data of observations carried out in 1960-1995 on hilly moraine agro-landscape have been published (*Hidrometrinis ..., 1995,* *1997*). These long-term and precise measurements taken in medium till formations of waterlogged lowlands on high hypsometric level may be used for the assessment of drainage, slope and ditch flow. Drainage, ditch and surface flow have also been measured in Antaniškis (Zarasai region) water measuring stations for a few years.

Data obtained on the analogy of Saldutiškis demonstrate that the maximum instantaneous drainage flow amounts up to 26.6 l s^{-1} km^{-2}, while the average for the wettest month (April) – 0.17 l s^{-1} km^{-2} (in some years – up to 0.26 l s^{-1} km^{-2}). The maximum drainage flow is in March and April. In recent years, with the increasing probability of warm winters, the drainage flow of winter increased as a result of more frequent thaws. It amounts up to 11.93 l s^{-1} km^{-2} (Table 4.1.1.6).

Table 4.1.1.6. Average and maximum drainage flow in hilly moraine agro-landscape, l s^{-1} km^{-2} (on the analogy of Saldutiškis)

Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Average	0.09	0.07	0.13	0.17	0.08	0.06	0.05	0.04	0.05	0.07	0.07	0.09
Maximum	10.41	5.90	26.60	22.47	7.47	3.98	2.12	2.97	2.60	4.55	5.19	11.93

During the melting of snow the maximum flow of land reclamation canals in hilly moraine agro-landscape reaches 80.44 l s^{-1} km^{-2}, while the average for the wettest month (April) is up to 15.99 l s^{-1} km^{-2} (Table 4.1.1.7). The average annual flow of land reclamation canals is 5.6 l s^{-1} km^{-2}; however, during the summer drought when underground nourishment prevails the canal flow is only from 1-3 l s^{-1} km^{-2}.

The surface (slope) flow is usually observed during the melting time in spring or during winter thaws. The duration is from 8 to 49 days (the average of 19 days). The maximum instantaneous surface flow established on the analogy of Saldutiškis is up to 142.7 l s^{-1} km^{-2}, while the average monthly flow – 0.89 l s^{-1} km^{-2} (*Hidrometrinis ..., 1997*). The surface flow with 90% probability (duration: 9 days), the average annual flow is 0.08 l s^{-1} km^{-2} (Table 4.1.1.8).

Table 4.1.1.7. Average and maximum ditch flow in hilly moraine agro-landscape, l s^{-1} km^{-2}

Month	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**	**VIII**	**IX**	**X**	**XI**	**XII**
Average	5.46	5.29	13.13	15.99	5.72	1.65	2.37	1.22	1.02	3.10	4.58	7.36
Maximum	19.90	27.86	80.44	58.11	35.67	7.51	10.59	4.30	3.93	9.57	13.29	30.88

Table 4.1.1.8. Probability of a surface flow in hilly moraine agro-landscape, l s^{-1} km^{-2}

Probability, %	**Average annual, l s^{-1} km^{-2}**	**Maximum, l s^{-1} km^{-2}**	**Duration, number of days**
10	3	125	24
50	0.21	16	17.5
90	0.08	3	9

Some basic water balances

As it has been mentioned already, territories that are candidate sites for the construction of the repository are of a hilly moraine agro-landscape nature. On the other hand, the key elements intended to be used in the construction of the repository shall be ridged steep hills. Therefore, comprehensive studies of hydrological and hydrochemical regimes of basic agro-landscapes (slopes around the lake) carried out in the 80's of the 20th C in the eastern part of Lithuania may be employed for the description of basic water balances of their slopes. Published data (*Dilys, 1986; Dilys, 1994 – 1995*) reflect the average values of 5 hydrological years (Table 4.1.1.9). Studies have been carried out in typical slope sections of 50 to 180 m in length.

Table 4.1.1.9. Some basic water balances of slopes under hilly moraine agro-landscape conditions of the eastern part of Lithuania

Indicator	Site 4(16) at Lake Vėlys	Site 7(18) at Lake Kemešys	Site 8(20) at Lake Ūkojas
Slope characteristics			
Exposure	North	North	Northeast
Soil	Glacial loam on light till	Average till on light till with a streak of clay under boulder	Clay
Steepness of the slope	5°	6°	3°
Water balance, mm			
Soil moisture content in the layer of 0-150 cm at the beginning of winter	371.6	454.5	496.5
Precipitation (cold season + warm season)	729.9 (188.3+541.6)	673.1 (152.5+520.6)	652.0 (140.7+511.3)
Surface flow	77.2	57.0	68.2
Infiltration deeper than 150 cm	237.3	245.2	188.9
Total evaporation	405.6	392.1	400.3
Soil moisture content in the layer of 0-150 cm at the beginning of next winter	383.6	430.4	489.7

Nature and condition of hydraulic installations

Different kinds of hydraulic installations exist in the environs of the sites; however, only a small number of them is important in terms of hydrological regime of the area. Such waterworks include:

1. The sluice (the so-called "Object 500") in the town of Drisviaty in Belarus on the Prorva canal that regulates the water level in Lake Drūkšiai. The sluice is important both for the operation of the nuclear power plant and for the hydrological regime of the area, as it affects the water level in Lake Drūkšiai and thus (through groundwater) the hydrogeological regime of a part of the basin of the lake.

2. The blind earth dam on the Drisviata river near the former confluence with the Apvarda river. This hydraulic installation changed the flow direction of the natural stream that used to flow out of Lake Drūkšiai, and in interaction with the abovementioned sluice it changed the regime of the water level in Lake Drūkšiai. If the dam disintegrates, the water level in the lake and the outflow from it can naturally return to the former condition.

We do not have any data on the blind earth dam on the Drisviata river; however, it should be noted that the Lithuanian-Belarus intergovernmental agreement regulates the operation of "Object 500" (the sluice) and does not regulate the operation of the dam on the Drisviata. According to the agreement between the Government of the Republic of Lithuania and the Government of the Republic of Belarus on "Object 500" and the "Tautų draugystė" hydro-electric power plant, there is an enclave of 1.31 ha in the settlement of Drisviaty in Belarus that belongs to the Ignalina NPP, which was transferred to the nuclear power plant by the resolution of the Executive Committee of Vitebsk region. The enclave has a sluice (code name: “Object 500”) on the Prorva river, which is required to preserve the water level in Lake Drūkšiai and which is entered into the balance sheet of the Ignalina NPP. The building of the “Tautų draugystė” hydro-electric power plant located 1.5 km downstream the Prorva river, Belarus, as well as the dam and intake, outlet and connecting canals are also entered into the balance sheet of the Ignalina NPP. The agreement of 6 February 1995 between the Government of the Republic of Lithuania and the Government of the Republic of Belarus on “Object 500” and the “Tautų draugystė” hydro-electric power plant states that in order to secure the safety of the Ignalina NPP and other energy units the Government of the Republic of Belarus transfers “Object 500” and its installations to the ownership of the Republic of Lithuania.

These installations are important as far as the probability of the alleged or potential flooding of repository sites is concerned; therefore, the absolute height of their upper pools is important. The upper pool of installations is described differently (“Object 500”: 143.1 m); therefore, the maximum water level of Lake Drūkšiai to be expected in emergency situations (when the sluice fails to let water through or when one of the installations breaks down) is unknown. The level of the dam on the Drisviata may be 144 m of the absolute level, i.e. approximately 2.4 m higher than the average perennial level of Lake Drūkšiai and 1.1 m higher than the level of Lake Apvardai. The altitude of the upper pool of the dam is 143.1 m, normal backwater level – 141.6 m, minimum water level – 140,7 m, and the maximum water level – 142.3 m.

Existing water consumers

Principal water consumers in the vicinity (area) of the Galilaukė, Stabatiškė and Apvardai sites are the Ignalina NPP using water of Lake Drūkšiai for cooling and the community economy and enterprises of Visaginas city using groundwater from the water extracting site located 1.5 km west of the Stabatiškė site, 2 km north of the Apvardai site and 3.5 km west of the Galilaukė site. Residents use groundwater from shaft-wells.

There are no irrigation fields or other significant surface or underground water supply systems, also artificial fish hatchery ponds in the vicinity of the sites (however, there used to be plenty of them a little bit further from the analysed territory, within the radius of 5-10 km from the potential repository sites; this direction will not be analysed any further due to insignificant relation to the topic of the study). There are underground water bores and water raising equipment in the vicinity of the sites.

General hydrogeological conditions

The general hydrogeological situation of the area in the profile up to the upper-middle Devonian aquiferous complex (the Šventoji-Upninkai) is described based on earlier research data (*Identification of Candidate ..., 2003*). Also, the description has been supplemented with the initial data of the research that is being carried out.

Groundwater in the openings and sandy inserts of the upper part of the moraine in the area south of Lake Drūkšiai is relatively high (near the surface) and is close to surface water according to the nature of the level regime. This water does not form any continuous or evident aquifer in moraine formations. Based on research data, the moisture content of the moraine does not reach the level of full saturation with water; therefore, moisture transfer mechanism of the aeration zone is characteristic to continuous moraine formations with the thickness of 15-20 cm, while the rate of flow of water accumulated in wells and bores located in the upper layer of the moraine is very low. Semi-confined and confined aquifers are twenty or more metres deep from the surface of the earth, and their safety conditions cause no reasons for any doubt.

Conditions for the formation of the soil run-off are similar in the area and depend upon the infiltration recharge of groundwater (Table 4.1.1.10).

Table 4.1.1.10. Infiltration recharge of groundwater subject to the characteristics of the aeration zone (*Map of the natural ..., 1985*)

Characteristics of rock in the aeration zone		**Parameters of infiltration recharge**		
Lithological content and genesis	**Storativity or water saturation, %**	**Module, $l/s\cdot km^2$**	**Speed, mm/m**	**Coefficient, %**
1. Limnoglacialic clay (lg III); peat (B IV)	<0.1	-7-0	-220-0	-35-0
2. Glacial loam and till (g III, gt III); limnoglacialic loam (lg III); fine-grained alluvial sand (a IV); marine (m IV), bog (b IV) and eolic (v IV) sand	0.1-5.0	0-1	0-32	0-5
3. Varigrained alluvial (a III, a IV); delta (a m IV), marine (m IV), lake (l IV), limnoglacialic (lg III) and fluvioglacial (f III) sand (aeration zone is up to 5 m in thickness)	5-15	1-3	32-95	5-15
4. Varigrained alluvial (a III, a IV); delta (a m IV), marine (m IV), lake (l IV), limnoglacialic (lg III) and fluvioglacial (f III) sand (aeration zone is up to 2 m in thickness)	5-15	3-5	95-158	15-25
5. Varigrained sand and sandy-gravely alluvial (a IV) and fluvioglacial (f III) formations (aeration zone is up to 5 m in thickness)	15-25	5-7	158-221	25-35
6. Varigrained sand and sandy-gravely alluvial (a IV) and fluvioglacial (f III) formations (aeration zone is up to 2 m in thickness)	15-25	7-9	221-284	35-45
7. Sandy-gravely-pebbly fluvioglacial (f III) formations and weathered pre quaternary rocks	>25	>9	>284	>45

GALILAUKĖ SITE

The Galilaukė site is located among Lake Drūkšiai and its tributaries of the Gulbinėlė and the Drūkša (Apyvardė). From the western and southern part of the site the surface water flows by land reclamation canals to the Drūkša. From the eastern part of the Galilaukė site the water flows along the swampy lake and land reclamation canals to Lake Drūkšiai, and from the north – to the Gulbinėlė rivulet (Fig. 4.1.1.2).

The principal surface elements of the Galilaukė site that determine the segmentation and structure of basic basins in the Galilaukė site and that are described in Chapter 4.1.4 are as follows: the Vosyliškės ridge (approximately 2 km in length east and west), ridged Galilaukė hill (1.2 km northwest and southeast) and the Švikščionys ridge (approximately 1.8 km in length northeast and southwest, along the Drūkša river; it is separated from the Drūkša by a 50-250 m wide swamp).

The relatively closed lowland consisting of the above relief elements has small island-like hills and waves varying in size. From the west the site is almost closed by the range of Varniškės hills and waves.

Hydrographical situation and characteristics of the flow

The principal hydrographical elements of the Galilaukė site are land reclamation canals, the Drūkša (Apyvardė) river and the Gulbinėlė rivulet, wetlands (swampy areas among hills, waterlogged lowlands of hills, swamps) and underground drainage. There are sources of water in the north-western part of the site, and homesteads with shaft-wells in the territory of the site and around it. The key divide of the location is the principal ridged hill of the Galilaukė site the south-eastern part of which is the junction of the basins of the Drūkša river, canal K-12 of the area among the hills, tributary K-2 of the southern bay of Lake Drūkšiai and the Gulbinėlė river (in the north) (Fig. 4.1.1.2).

The Drūkša river and riverside swamps drain the south-eastern slope of the Švikščionys ridge and the southern slope of the Vosyliškės ridge; furthermore, the river is the water inlet of the said basin of the area among the hills (land reclamation canal K-8). The width of the river is 15-25 m, the depth is up to 2 m, the flow is very slow – <0,1 m s^{-1}. The depth of the riverside swamps is approximately 1.5 m. The rather closed swampy lowlands surrounded by ridges and ridged hills are drained by main canal K-12 (to the bridge of the Galilaukė-Vosyliškės local road) and K-10 (down the bridge). It flows into K-8, which runs along the Varniškės ridge (it has a short left-bank tributary K-3; the canal from the point of its outflow to the tributary is called K-7 (Table 4.1.1.9)). The inclination of the system of land reclamation ditches (from the bottom level at the point of outflow to the water surface of the Drūkša river) is approximately 5-5.5 m (about 0.0019 m/m).

In this region, complex hills of a heavy mechanical structure are characterised by waterlogged lowlands situated on different hypsometric levels. The principal Galilaukė hill does not have such lowlands (except wet points of outflow of short washes on the south-western and southern slopes). The said lowlands can be found in the Švikščionys ridge. They are located on the absolute levels of 157-159 m (the hollow in the area among the hills –s approximately 149 m, while the Drūkša river – approximately 141 m of the absolute level). The comparative depth of the lowlands: 1-3 m. On 25 June 2004, there was water (up to 0.5 m in depth) in the lowlands of the hills, and there were signs of permanent waterlogging (judging from the soil, flora and fauna). At the end of 2003 there was no water in the said lowlands; however, the signs of waterlogging were obvious.

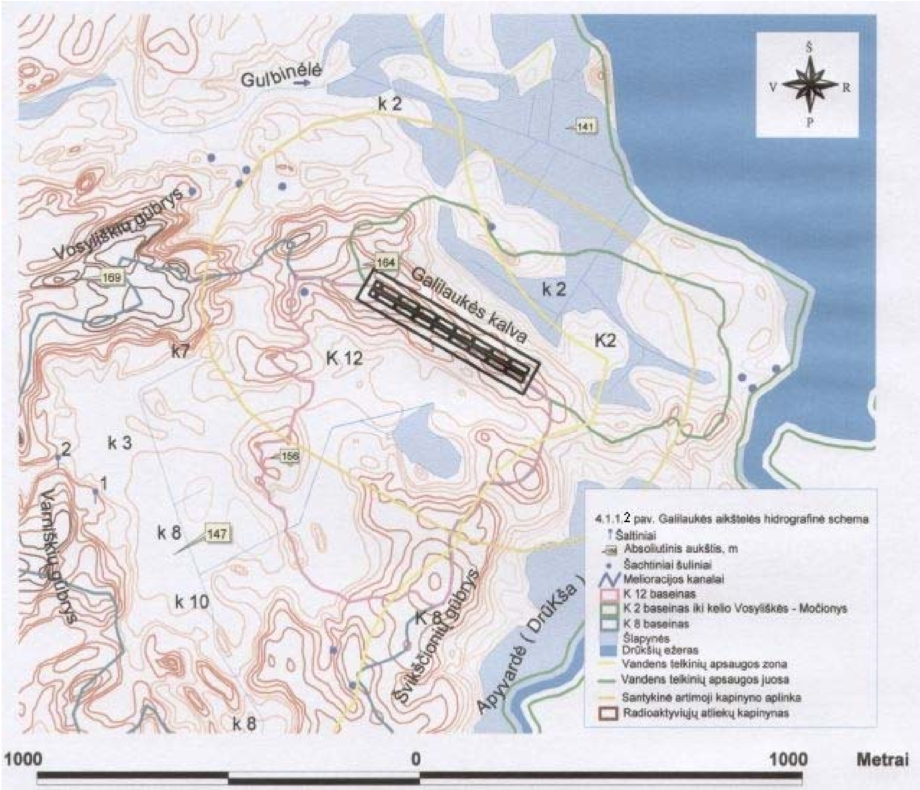
Considering the locality of the object, the hydrographical characteristics of the north-eastern part of the site is important (because of the position of the principal Galilaukė hill as the divide).

The Varniškės ridge is the divide between K-8* flowing to the northeast-north to the Gulbinėlė, and K-8 flowing southwards to the Drūkša. There are some semi-wet areas on eastern and northern slopes of the Varniškės hills, slightly higher that the foot of the hill (and wetlands overgrown with bushes on the eastern slope).

There are two springs at the north-eastern foot of the Varniškės hills. The first spring is located 60 m to the right from the field road from Varniškės to Galilaukė (along the outskirts of the forest), at the north-eastern foot of a high hill, on the approximately 1 m ascent, in the field with no bushes, some 30 m away from a wet small hollow overgrown with bushes. Two concrete curbs (diameter: 0.8 m) have been dug in to draw water. The top of the concrete curb is 0.24 m above the surface of the earth. The level of water inside: 0.11 m above the surface of the earth. Water runs through cracks. The depth from the surface of water: 1.87 m; the bottom is hard. Water flows to the north–northeast, without forming a bed. There are ferrous deposits around. The spring is in use, and there is a water-trough installed. The second spring is located 20 m to the left from the field road from Varniškės to Galilaukė (along the outskirts of the forest), 80 m away from the first spring. The spring is at the mouth of a deep wash, beside the last large trees, nearer to the left bank of the wash. The wash is overgrown with alders, various bushes, cat's-tails and nettles. There is also a concrete curb in the spring. The upper part of the curb is some 0.5 m above earth; it is significantly decayed. The spring is choked up almost to the surface of the earth; there are only traces of water. The local residents say that the spring started to sink following land reclamation. Water flows from the wash to the northeast, without forming a bed. The absolute height of the surface of water of both springs is approximately 149-150 m.

Description of land reclamation systems

The description of the hydrographical situation of the site mentioned that there are land reclamation canals (Table 4.1.1.11) and the underground drainage network in the analysed area. No detail design plans of the latter have been found; however, it could be assumed by analogy that drains were built every 20 m.



Galilaukės kalva	Galilaukė hill
Vosyliškių gūbrys	Vosyliškės ridge
Švikščionių gūbrys	Švikščionys ridge
Varniškių gūbrys	Varniškės ridge
4.1.1.2 pav. Galilaukės aikštelės hidrografinė schema	Fig. 4.1.1.2. Hydrographical scheme of the Galilaukė site
Šaltiniai	Springs
Absoliutinis aukštis, m	Absolute height, m
Šachtiniai šuliniai	Shaft-wells
Melioracijos kanalai	Land reclamation canals
K 12 baseinas	Basin K 12
K 2 baseinas iki kelio Vosyliškės – Močionys	Basin K 2 up to the Vosyliškės-Močionys road
K 8 baseinas	Basin K 8
Šlapynės	Wetlands
Drūkšių ežeras	Lake Drūkšiai
Vandens telkinių apsaugos zona	Protection zone of water bodies
Vandens telkinių apsaugos juosta	Protection strip of water bodies
Santykinė artimoji kapinyno aplinka	Relative short-range environs of the repository
Radioaktyviųjų atliekų kapinynas	Radioactive waste depository

Table 4.1.1.11. Characteristics of main canals of the Galilaukė site

Section	Length, km	Width*, m	Depth, m	Remarks
K-7 (to the northeast-southwest to the turn)	0.25	3 - 5	Up to 1.5	-
K-7 (southwards to the junction with K-3)	0.38	4 - 6	Up to 1.5	-
K-3 (to the northeast-southwest, tributary K-7 from the left)	0.1	3 - 5	Up to 1.2	-
K-8 (from the junction of K-7 and K-3 to the inflow of K-10 from the	0.24	4 - 6	Up to 1.5	The width of the flooded area: 1-1.2 m; bushes in the canal are up to 2 m

Section	Length, km	Width*, m	Depth, m	Remarks
left)				in height
K-12 (from the swamp in the area among the hills to the bridge of the Galilaukė-Švikščionys field road)	0.8	6 - 8	2 – 4	The level of water in the canal: 0.1-0.3 m. Rate of flow: 2 l/s (on 5 July 2004). There are bushes, orchis, cowslips and cat's-tails in the ditch. The ditch has been dug up to the mineral soil.
K-10 (from the bridge of the Galilaukė-Švikščionys road to the juncture with K-8)	0.3	4 - 6	1.2 – 2	The level of water in the canal: 0.3 m. The flow is barely noticeable. The area flooded by water: 1-1.2 m. Water weeds, arrowheads, cat's-tails and thick bushes.
K-8 (from the juncture with K-10 to the Švikščionys-Beržininkai road)	1.2	6 - 8	1.5 – 4	Flows into the Drūkša river in 0.6 km.
K-2 (from the point of outflow to the Vosyliškės-Mačioniai road)	0.3	-	-	flows into the place round the swamp of Lake Drūkšiai. Flowed from the lake to the swamp (on 5 July 2004). The rate of flow was 3 l/s.

* According to plans of the land use, the stated canal system covers the area of 3.2 ha, and the length of canals is 3.1 km; therefore, the average width of the canal should be 10. The actual width is less.

The swampy foot of the north-eastern slope of the Galilaukė hill is drained by the system of shallow ditches (K-2), which is directly connected with both Lake Drūkšiai and the Gulbinėlė river (by the swampy Vosyliškės forest) (Fig. 4.1.1.2). The distance between the foot of the Galilaukė hill and Lake Drūkšiai in the northeast and the Gulbinėlė river in the north is barely 0.6 km. The water level in canal K-2 should be similar to the water level in the lake; however, at the start of a rainy summer (25 June-5 July 2004), the lowest 20 m section of the Mačionys-Vosiliškės road (at K-2) was flooded (the depth: 0.3 m). Water used to flow at different directions, depending upon the level of water in Lake Drūkšiai, canal K-2 and wetlands of Vosyliškės forest. At the end of 2003, the road was flooded; however, the flooded section was less than 10 m. On 13 July 2004 water was flowing to the direction of the lake, and the rate of flow was 1.8 l s^{-1}.

The basin area of K-2, which drains the foot of the north-eastern slope of the Galilaukė hill, is approximately 51.1 ha, the density of land reclamation canals is 2.59 km km^{-2} (the basin of K-2 continues to the viaduct of the Vosyliškės-Mačionys road). The basin area of K-12 (to the bridge of the Galilaukė-Švikščionys road) is 62.5 ha, the density of land reclamation canals is 1.28 km km^{-2}. About ¾ are covered with slopes of hills, isolated waves and steep shores of the lake, and the remaining part – with drained peatbogs.

The present-day hydrographical network of the basin of K-12 emerged after land reclamation carried out in 1971-1973 (the project was developed in 1969). Prior to land reclamation, the said area among the hills was low-lying swampy land with deep bogs: peatbogs of up to 7.2 m deep in the north, 3.5 m deep in the southeast, 1-2 m deep in the area among hills, and 5-7 m deep at the point of outflow of the basin (the bridge of the Galilaukė-Švikščionys road). Following land reclamation the peatbogs settled to the (preliminary) thickness of the peat layer of 1.5-2 m. After annual peat fires (as of 1995), sporadic 0.5-1m-deep pits (or in some places – cinder up to the mineral soil; they overgrow with aspens and birch, the grassland undergoes changes, and tormentils, campions and campanulas become wide-spread, which indicates the change of acidic/alkaline conditions) appeared at the point of outflow of K-12 and at the junction of K-10/K-8.

Land reclamation basically changed the structure of the hydrographical network of the basin. Prior to land reclamation, shallow water-deferent ditches prevailed in the basin; during land reclamation they were replaced with main canal K-12 and underground drainage collectors. Prior to land reclamation, the basin had approximately 2.6 km of ditches (mostly by-pass canals running at the foot of slopes and on the edges of swamps). Following land reclamation, only 0.8 km of ditches remained, and a result the density of beds decreased from 4.3 km km^{-2} to 1.28 km km^{-2} . In June 2004, no drainage collectors were detected in canal K-12 (due to thick grass and bushes; the condition of the drained meadow allows to conclude that the efficiency of drainage is average).

On 25 June 2004, the rate of flow in a reinforced concrete pipe (diameter: 0.9 m) of the bridge of the Galilaukė-Švikščionys road was approximately 1.2 l s^{-1}, and the speed of flow – 0.1-0.2 m s^{-1}. The run-off from basin K-12 was approximately 2 l s^{-1} km^{-2}. In canal K-8, the run-off occurs only during the melting of snow and after heavy raining. When the raining stops, the run-off becomes weaker and then stops altogether. On 13 July 2004, the rate of flow in canal K-12 was only 0.05 l s^{-1}, and only 0.6 l s^{-1} in canal K-8.

Each spring, surface water is present in lowlands and the foot of drained slopes of hills for a long time, even though the level of water in the wells of residents living near-by is rather low at that time. In Galilaukė, the well of the Saulevič homestead dries up every summer (the level of water on 5 July 2004: 2.8 m). Then water is delivered from neighbouring Varniškiai village or from the spring (the first spring shown in Fig. 4.1.1.2) located in the north-western part of the site (the rate of flow of the spring: 200 l/h). Fig. 4.1.1.3 provides the summarised view of the discussed elements of the water balance in the Galilaukė site.

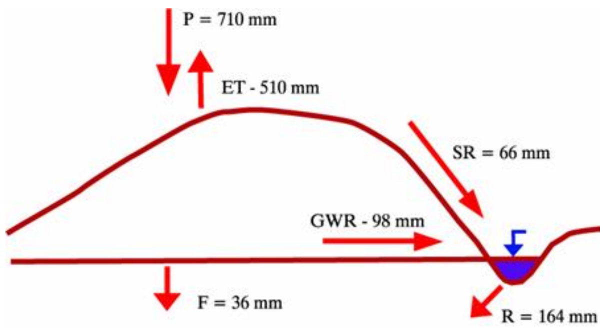


Fig. 4.1.1.3. Summarised water balance in the Galilaukė site: P – atmospheric precipitation, ET – evaporation, SR – surface run-off, GWR – groundwater run-off to rivers and drains, and R – outflow.

Nature and condition of hydraulic installations

The principal hydraulic installations in the site are overflows of land reclamation canals. Their condition is satisfactory. Water running from the swamp located at the foot of the northern slope of the Galilaukė ridge (k-2) reaches the lakeside swamp by overflowing the road instead of using the overflow.

The condition of the underground drainage is controversial: part of it functions satisfactory; however, there are signs of long-term waterlogging already. No drainage collectors have been detected so far; therefore, their condition is unknown. Further north from the site area, there is a hydrometric rift of a good technical condition on the Gulbinėlė rivulet beside the bridge.

Probability of flooding of the site

The proposed altitude of the bottom of the repository at the Galilaukė site would be 150 m. Based on the probability of the change of water level in Lake Drūkšiai and in the Drūkša-Apyvardė, the flood water will not reach this altitude (Table 4.1.1.5). Even the complete closure of the dam of Object 500 would leave a reserve of approximately 7 m. On the other hand, the complete closure of the dam of Object 500 and the rise of water to the altitude of 144 m (reserve: 6 m) would result in the flow in two directions, i.e. along the Prorva and the Drūkša. Thus, the surface water would never reach the bottom of the repository of the Galilaukė site even during the strongest of the floods.

Existing water consumers

Other water consumers in the site and its vicinity are local residents that use groundwater from shaft-wells or from the Varniškės spring for their household needs. The spring is installed (adapted for drawing water and for watering cattle); however, the old access to the spring no longer exists. According to local residents, the supply of drinking water is a constant problem of Galilaukė. A bore (bored at the request of residents) at the foot of the hill (southern exposure) of the rural homestead of Galilaukė showed that at the end of 2003 water was at the depth of 4.5 m.

Local residents say that on the Švikščionys ridge, water does not disappear in wells each year; however, it is a sufficiently significant problem of the locality. Water is always present in the wells of homesteads on the Varniškės ridge; there are ponds in homesteads to the west of the ridge.

Hydrogeological conditions

The described area has 60-200 m thick Quaternary aqueous rocks of the glacial origin, and Pre-Quaternary (Devonian, Silurian and Ordovician, Cambrian and Upper Proterozoic) rocks underneath. Metamorphic and crystalline rocks occur in the depth of 700-750 m. The upper part of the thickening of Quaternary rocks that was formed during the retreat of the last glacier is not integral. During the post-glacial era, alluvial, lake and swamp formations were formed. The lithological content of surface formations determine filtration and strength characteristics of the soil. The lithological content of the soil in the site and its vicinity is not very diverse: on the surface, up to 10 m are low permeable till and clay soils. Silt gravel and sand is found in the Gulbinėlė valley and in lowlands among the hills. A layer of peat (up to 7 m) that settled following the land reclamation occurs above silt sediments in the lowlands among the hills. To the west and northwest from the Galilaukė site, a clear soil aquifer consisting of gravel and sand occurs some 5 m from the surface. It does not form a continuous aquifer, and surfaces in some places in the Gulbinėlė valley as well as in lowlands lined with channels.

An aquitard (g II gr, gII md) formed of till and glacial loam occurs beneath the upper first low permeable layer (gt III bl); the aquitard can be as thick as 40 m. Till (g III gr) surfaces in some places of eroded hill slopes. A solid (as far as the site and its vicinity is concerned) semi-confined-confined aquifer (f II žm) consisting of various sands occurs beneath the first aquitard; the aquifer can be as thick as 10 m. Its water pressure in the site environment changes from 137.7 to 134.9 m and is lower than the water level of Lake Drūkšiai (141.6 m). The second aquitard (g ii žm) formed of till and glacial loam occurs beneath the first solid aquifer; the thickness of this aquitard is 5-15 m (Fig. 4.1.1.4).

Low permeable zones of the Galilaukė site have the following characteristics: thickness – 30 m, density – 2.2 g/cm^3, porosity – 0.25, effective diffusion coefficient – $1 \cdot 10^{-6}$ cm^2/s, filtration coefficient – $1 \cdot 10^{-5}$cm/s (conservative assessment).

The aquifer of the Galilaukė site has the following characteristics: thickness – 10 m, density – 2.2 g/cm^3, porosity – 0.3, filtration coefficient – $2.5 \cdot 10^{-2}$, gradient of water level (pressure) – 0.0008 m/m; (Darcian) flow speed – $2.0 \cdot 10^{-5}$ cm/s.

The water transfer path, which is important from the security point, is in the central part of the hill (vertical transfer is in till as in the aeration zone, and horizontal transfer is in semi-confined-confined aquifer). The point of the discharge of the aquifer is the well (bore into groundwater), 150 m away from the vaults of the repository.

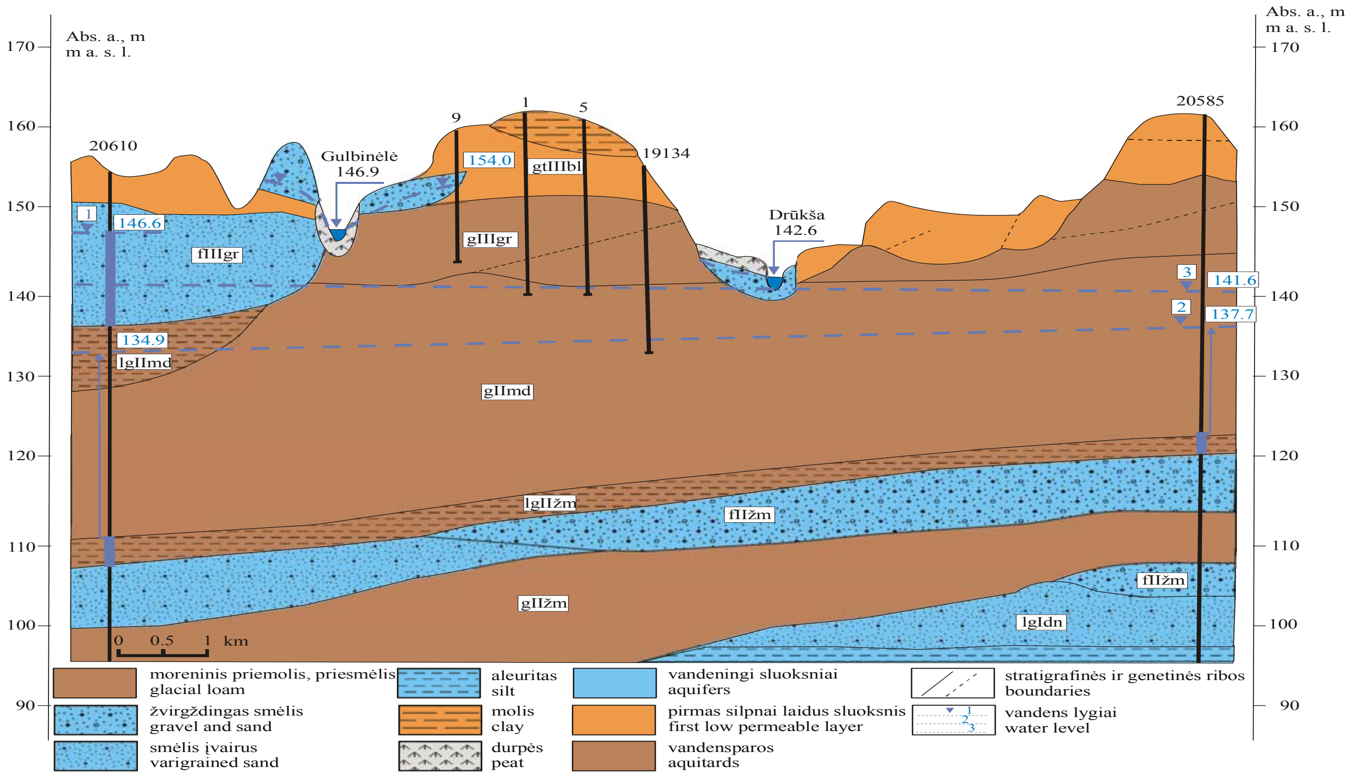


Fig. 4.1.1.4. Hydrogeological profile of the Galilaukė site and its environs, adjusted according to the study data of 2003 and 2004. Water levels: 1 – groundwater, 2 – semi-confined-confined aquifer, 3 – Lake Drūkšiai. The site of the hydrogeological profile is shown in Fig. 4.1.5.4 (C-C section of the profile between bores No. 20610 and No. 20589).

Hydrochemical characteristics

Water sampled from surface water bodies and bores in the Galilaukė site should be classified as calcium bicarbonate type of water. The bicarbonate content varies from 280.6 to 585.6 mg l^{-1}. The bicarbonate content is higher in bores, while it is almost twice as low in water bodies (Table 4.1.1.12). The chloride content is higher in surface water bodies (Gulbinėlė and K-2); this is predetermined by wastewater of Visaginas. It is not clear why bore No. 5 has a comparatively high content of chlorides (25.56 mg/l). This bore also has a comparatively high content of nitrates (0.703 mg/l) and general nitrogen (2.132 mg/l).

Table 4.1.1.12. Chemical composition of water in the Galilaukė site on 5 July 2004

Place	HCO3-	Cl-	SO42-	NO2-	NO3-	NH4+	Na++K+	Ca2+	Mg2+	B. solid	B. mineral
	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg-equiv/l	mg/l
K 12	341.6	2.84	63.0	0.077	0.857	0.710	0.61	93.86	27.86	6.89	531.43
Gulbinėlė	231.8	31.24	5.8	0.333	3.856	0.276	40.76	36.10	17.45	3.24	367.61
K 2	280.6	17.04	<2	0.000	0.358	0.864	24.54	47.65	20.93	4.10	393.99
Bore No. 5	561.2	25.56	14.0	0.703	0.108	0.515	72.12	93.86	32.24	7.34	800.30
Bore No. 6	561.2	8.52	17.4	0.073	1.075	0.202	36.74	79.42	53.27	8.35	757.90
1 st.	402.6	5.68	16.3	0.057	1.058	0.512	19.55	41.88	51.59	6.34	539.21
2 st.	585.6	1.42	15.1	0.120	3.227	0.470	12.63	64.98	76.06	9.50	759.61

Place	BO	PO	N/NO2 -	N/NO3 -	N/NH4 +	N min.	N org.	Nb.	Pb.	P min.	P org.
	mgO/l	mgO/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
K 12	57.13	29.76	0.023	0.198	0.552	0.773	0.808	1.581	0.044	0.033	0.011
Gulbinėlė	34.28	15.04	0.100	0.871	0.215	1.186	0.873	2.059	1.667	0.528	1.139
K 2	57.13	26.88	0.000	0.081	0.672	0.753	0.424	1.176	1.778	0.611	1.167
Bore No. 5	62.84	14.08	0.211	0.024	0.401	0.636	1.496	2.132	0.061	0.011	0.050
Bore No. 6	22.85	3.20	0.022	0.243	0.157	0.422	0.093	0.515	0.000	0.000	0.000
1 st.	5.71	3.52	0.017	0.239	0.398	0.654	0.081	0.735	0.000	0.000	0.000
2 st.	2.88	0.036	0.729	0.366	1.131	0.046	1.176	0.000	0.000	0.000	0.000

With due consideration to the content of nitrogen and phosphorus compounds as well as the content of organic substance, water in surface water bodies does not meet the requirements for drinking water. With due consideration to the analysed parameters, streak groundwater in certain bores also fail to meet the requirements applicable to drinking water.

APVARDAI SITE

The Apvardai site is located between the Gaidė rivulet and swamps drained by the rivulet in the east and Lake Apvardai and lakeside swamps in the southeast. The area is drained by land reclamation canals extending to the south and southeast.

Soil and surface earth (medium and heavy clay loam) of the site, the relief (large and smaller swampy lowlands), small general inclination of the area fail to create favourable conditions for a speedy removal of surplus precipitation. Therefore, the land reclamation system of open canals and underground collectors has been constructed in the north-western section of Lake Apvardai in order to drain the site and the surrounding areas. The site belongs to the direct basin of Lake Apvardai (Table 4.1.1.13).

Table 4.1.1.13. Characteristics of Lake Apvardai

Lake No.	33-12
Area, ha	550.2/424.8*
Average depth, m	2.65
Deepest point, m	4.97
Volume of water, thousand m^3	14,596.0
Area of the basin, km^2	134.5
Transmissivity, % per year	218
Effluent	Apyvardė

* Total/in the territory of Lithuania

Tributaries of Lake Apvardai include the Žilma (which brings the flow from lakes Ilgiai, Alksnas, Prūtas, Rūžas and Žilmas), the Gaidė (which brings the flow from lakes Samanis (Pasamanis) and Gaidė) and three land reclamation canals in the north-western section of the lake. The annual water circulation of Lake Apvardai is rather intensive, viz. 218%. The western and southern shores of Lake Apvardai are swampy.

Hydrographical situation and characteristics of the flow

The Apvardai site is approximately 1,300 m away from the north-western section of Lake Apvardai, north of the Čepukai-Bieniūnai road. The site is drained by canals K-6 and K-4; canal K-4 connects the system of several canals. Canal K-6 collects surface water from the eastern and south-eastern section of the site. Then water flows towards Apvardai;

however, it empties into a lakeside swamp some 600 m short of the lake. Canals K-8 and K-6** (another canal marked by the same number) carry water from the central part of the site to canal K-4, from where water flows another 800 m and empties into Lake Apvardai. The south-western side of the site is drained by the system of land reclamation canals flowing into canal K-4. Some of the central and northern parts of the site belong to the bolson (Fig. 4.1.1.5). The hydrographical structure of this basin is still being specified. A small inclination between the southern section of the site and the mouth of canal K-4 fails to create favourable conditions for a speedy removal of surplus water. On 5 July 2004, the level of water in the canal north of the Čepukai-Rimšė road was >1 m.

The principal surface elements (described in more detail in Chapter 4.1.4) of the Apvardai site that determine the segmentation and structure of basic basins are as follows: the Bieniūnai ridge (approximately 1.5 km in length southeast and northwest) in the west, the Kumpiai hill and adjacent hills – the watershed between canal K-8 and canal K-6 (1.7 km southeast and northwest) in the northeast, Vigutėnai-Žibakiai ridge (approximately 2.3 km in length southeast and northwest) in the east, and the Tripuckai ridge – the watershed ridge (between the basins of Lake Apvardai and Lake Drūkšiai) stretching to the southwest and northwest in the north and northwest.

The said relief forms divide the site into two wet lowlands stretching to the southeast and north, which are being drained by land reclamation canals leading to Lake Apvardai.

Land reclaimed lowlands feature settled peat soil. Principle relief structures feature hills and waves of various sizes (1-5 ha) shaped like a peninsula and intervening into the said lowlands. Lowlands situated more to the east are divided by the former Girdžiūnai hill stretching from the southwest to the northeast. The lowlands separated by this hill had a closed 0.9m-long land reclamation canal (Fig. 4.1.1.5) that drained stagnant land (bolson K). As a result of the potential nonconformity of the surface and underground hydrographical network, the hydrographical situation of this area, which is important for the control of surface and underground flow, should be further specified.

The principal hydrographical elements of the Apvardai site are land reclamation canals, wetlands (swampy areas among hills, waterlogged lowlands of hills, lakeside swamps) and underground drainage. Lakeside swamps of Lake Apvardai start in the southern side of the site. There are several homesteads with shaft-wells within the territory of the site and around it (Fig. 4.1.1.5). No springs have been detected. However, there are waterlogged lowlands on high hypsometric level as well as deep pits filled with water (north-eastern area of the site).

Description of land reclamation systems

Major land reclamation was carried out around 1972. Prior to that, the swampy lowlands of Žibakiai-Girdžiūnai were drained by shallow ditches. They formed the grounds for the present main canals. There was no canal K-9 in the northeast of the site.

The territory of the site is drained by canals K-4 and K-6 as well as lakeside swamps and closed lowlands of various sizes. The canals are 3-8 m wide and 1-2.2 m deep (Table 4.1.1.14). The inclination of the system of land reclamation ditch K-8 is approximately 3.6 m (approximately 0.0033 m/m). Canal K-4 drops only by 0.2 m (0.0002 m/m); therefore, water in the canal is either slack or hardly flows.

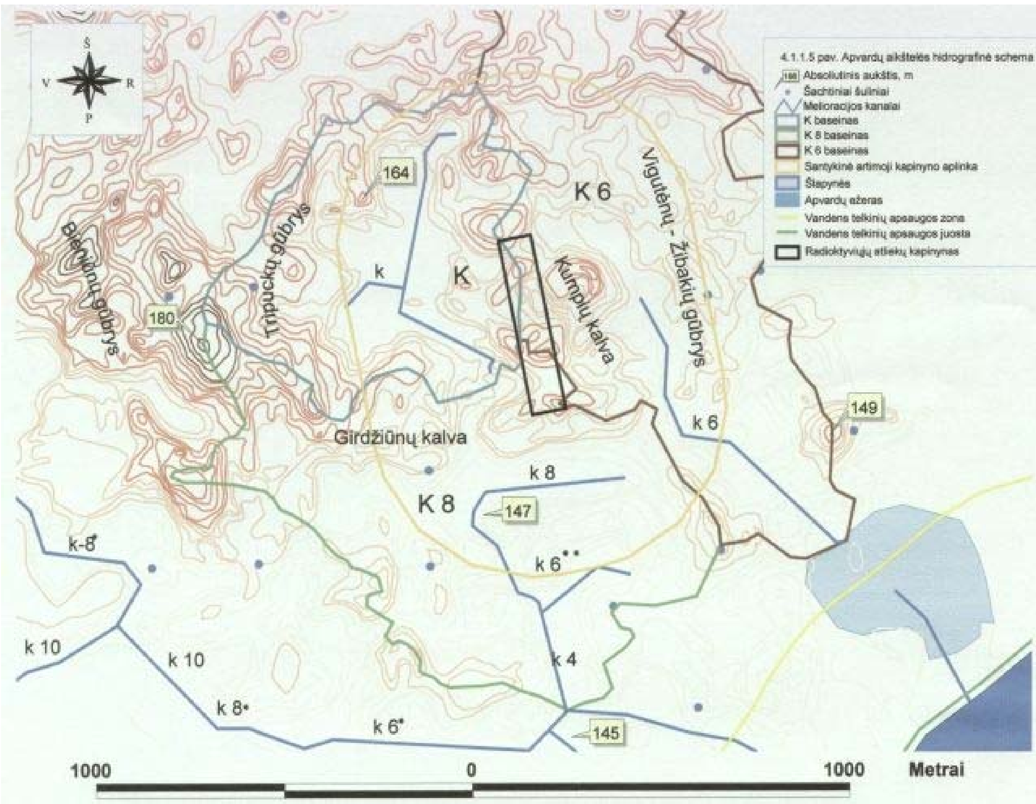
Drained swamps have never been deep (approximately 2.5-4.5 m, except for the shores of Lake Apvardai and swamps to the east from Girdžiūnai, where peat were more than 7 m thick). Drains have been constructed every 20 m.

From the east, the territory is drained by K-6, which commences between the Kumpiai forest and Vigutėnai village and flows to the southeast. Its length is 1.2 km, and it flows into a swamp in Žibakiai village. It may be connected with the canal that flows from the said swamp to Lake Apvardai across the Rimšė-Gaidė road. The length of this canal is 0.5 km, the width is approximately 10 m, and its bed is overgrown. Water flows by stream in the canal; the rate of low – approximately 0.4 l s^{-1}. The inclination of canal K-6 is approximately 7.9 m (approximately 0.0065 m/m); however, after it reaches the swamp, the drop in the water level is only about 0.1 m.

Considering the locality of the object, the hydrographical characteristics of canals K-8 and K-6 stretching along the western sink of the site. Stagnant canal K drains the northern foot of the Girdžiūnai hill, which also drains Pavarė meadows. The southern foot of the hill is drained by canal K-6, which has a very small inclination at the confluence with canal K-6*. Canal K-6 has the best flow conditions; however, it empties itself into a lakeside swamp with a small inclination.

According to the hydrographical network and hypsometry, the general inclination of the territory and its vicinity is to the southeast, towards Lake Apvardai. The foot of the Mikštas hill situated in the northern part of the territory has no springs, yet it has small lowlands bearing the signs of being waterlogged. During land reclamation, sinks have been formed in the southern and south-eastern foot of the slope, stretching towards K-8.

Canal K collects surplus water in the closed semi-wet meadow of Pavarė. It does not have any surface connection with any other canal or Lake Apvardai (preliminary; possible underground hydrographical or hydrological connection). The area of this bolson is 66.6 ha, and the density of the hydrographical network is 1.05 km km^{-2}.



4.1.1.5 pav. Apvardų aikštelės hidrografinė schema	Fig. 4.1.1.5. Hydrographical scheme of the Apvardai site
Absoliutinis aukštis, m	Absolute height, m
Šachtiniai šuliniai	Shaft-wells
Melioracijos kanalai	Land reclamation canals
K baseinas	Basin K
K 8 baseinas	Basin K 8
K 6 baseinas	Basin K 6
Santykinė artimoji kapinyno aplinka	Relative short-range environs of the repository
Šlapynės	Wetlands
Apvardų ežeras	Lake Apvardai
Vandens telkinių apsaugos zona	Protection zone of water bodies

Vandens telkinių apsaugos juosta	Protection strip of water bodies
Radioaktyviųjų atliekų kapinynas	Radioactive waste depository
Vigutėnų-Žibakių gūbrys	Vigutėnai-Žibakiai ridge
Kumpių kalva	Kumpiai hill
Tripuckų gūbrys	Tripuckai ridge
Bieniūnų gūbrys	Bieniūnai ridge
Girdžiūnų kalva	Girdžiūnai hill
Metrai	Metres

Table 4.1.1.14. Characteristics of main canals of the Apvardai site

Section	**Length, km**	**Width, m**	**Depth, m**	**Remarks**
K-6 (to the lakeside swamp)	1.2	8	2.1	-
K-8 (to the juncture with K-6*)	1.2	6-10	2-4	-
Left tributary of K-8	0.3	6	1.8	-
K-4 (from K-6* to Lake Apvardai)	0.85	3-5	up to 1.8	The area of the flooded section: 1.5-2.5 m; the level of slack water in the canal exceeds 1 m.
K-6* (from the Bieniūnai-Čepukai road bridge to K-4)	0.85	5	1.8	Slack water in the canal.
K (bolson)	0.9	5	1.7	The canal drains semi-wet Pavarė meadows; slack water in the canal.

The major section of the area is drained by K-8 and its left tributary K-6**. At Girdžiūnai it joins K-6*, which flows from the west. The length of canal K-6 – K-4 from the junction to the lake is 0.9 km. There are semi-wet lowlands and hollows filled with water on high hypsometric level in the divide between the point of outflow of K-8 and eastern canal K-6, in the north-eastern part of the area. The length of K-8 is 1.2 km, the area is 6-10 m, and the depth is 2-4 m. The bottom is overgrown, there is plenty of water. The width of the flow in the lower section at the homestead is 4-5 m, the depth is approximately 1 m. The flow is invisible; however, there are signs of flow, as the waterway is clean. Left tributary K-6**, which flows from the flattened territory, is 0.3 km in length and about 4-5 m in width. There is water; the flow is invisible. The area of the basin of K-8 (up to canal K-4) is 105.2 ha, and the density of land reclamation canals is 1.14 km km^{-2}. The area of the basin of K-6 up to the lakeside swamp is 114.8 ha, and the density of land reclamation canals is 0.94 km km^{-2}

In this region, complex hills of a heavy mechanical structure are characterised by waterlogged lowlands situated on different hypsometric levels. The hills of the Apvardai site also have isolated lowlands of such type, usually overgrown with bushes. The comparative depth of the lowlands: 1-3 m. There are signs of permanent waterlogging (judging from the soil, flora and fauna).

The network of land reclamation canals appeared as a result of land reclamation carried out approximately in the 1970's. Prior to land reclamation, there were deep bogs in the lowlands among the hills; as a result of land reclamation, peat bogs settled. The territory south of K-8 has been flattened and prepared for the construction of greenhouses. The flattened area does not show any signs of waterlogging (it is overgrown with clovers that overshadow spruce plants. There was a dense network of drainage in the flattened area. No operating collectors have been detected; they could have been flooded after peats settled. Land reclamation has changed the structure of the hydrographical network of the basin. Small swamps dominated prior to land reclamation that carried water to Lake Apvardai. As a result of land reclamation surplus water is more quickly removed from waterlogged areas.

Fig. 4.1.1.6 provides the summarised view of the discussed elements of the water balance in the Apvardai site.

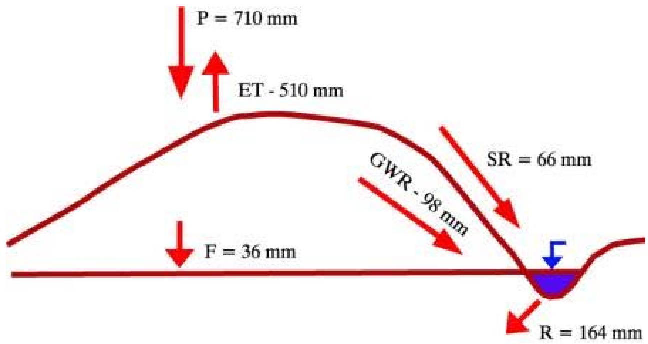


Fig. 4.1.1.6. Summarised water balance in the Apvardai site: P – atmospheric precipitation, ET – evaporation, SR – surface run-off, GWR – groundwater run-off to rivers and drains, and R – outflow.

Nature and condition of hydraulic installations

The condition of land reclamation canals is good and satisfactory in the reclaimed area and poor in the southern environs of the site, as ditches are not being cleaned. The condition of overflows of land reclamation canals is satisfactory in the site, while the condition of the important overflow (used for the run-off of water of the eastern side of the site) on the Gaidė-Rimšė road is bad, as water runs near the overflow. Installations on the shore of Lake Apvardai that were meant for the greenhouses have been destroyed. The condition of the dyke separating Lake Apvardai from drained settled meadows is satisfactory.

There are underground water bores in the vicinity of the site; however, nothing is known about their technical condition or status. The system that used to supply water to pastures in the 70's has been destroyed (currently, it is a reclaimed area).

Probability of flooding of the site

The altitude of the bottom of the repository at the Apvardai site would be 154 m. The established 1% probability of floods of Lake Apvardai (which was established with due consideration to the probability of floods of Lake Drūkšiai) should reach the altitude of 144.05 m. As a result of unforeseen circumstances (artificial blocking of the Prorva canal with the earth dam remaining at the confluence of the Apyvardė and the Drūkša, etc.) the water level may reach the altitude of 146-146.5 m during the potential strongest floods in Lake Apvardai. Thus, the surface water would only come close to the Apvardai site and would never reach the bottom of the Apvardai repository even during the strongest of the floods.

Other existing water consumers

There are no water consumers in the territory of the site. Formerly, water was consumed by several homesteads. During the existence of the Apvardai collective-farm, a water supply system for the watering of cattle was installed in the area flattened in the 1960's-1970's and in adjacent pastures. In the 1970's, the construction of the water supply system was planned for the greenhouses, and the shore of Lake Apvardai at Žibakiai was transformed as a result (a good beach was destroyed and the only access to the place was to be the site of the construction of the hatchway; there as a dyke on the eastern shore of the lake protecting from the flooding of the lakeside; preparations were made for the construction of the water supply system in the north-eastern section of the site – *unofficial* *data*).

Description of hydrogeological conditions

Groundwater occurs in the 1-3 m depth in the major part of the site and in all flattened area. From the lithological point of view, the aeration zone consists of glacial loam and till. In the territory of the site the hills are formed of glacial loam with (sandy) veins of a lighter composition and till streaks.

Hydrogeological conditions of the site are described by three 16-20 m deep bores installed in 2004. In spite of a small distance among the bores, the settled water level was different during the installation of the bores (at the beginning of June 2004): in the eastern side, water occurred in the depth of 3.6 m, in the middle of the hill – in the depth of 1.2 m, and in the north-western side of the hill – in the depth of 11 m.

A more detail analysis of the bore material has led to the making of the hydrogeological profile (Fig. 4.1.1.7). A thin sand and clay aquifer (lgt IIIbl) shows in the first low permeable layer (gt III bl). Here, the level of water occurs in the depth of 2.2 m in the range of the sand layer, and in the depth of 1.2 m – in the range of clay. A 6-12m thick aquitard (gt III gr) occurs below the first low permeable layer. A semi-confined aquifer (f II-III md-gr) with the thickness of up to 2 m and consisting of clayey sand occurs beneath the first aquitard. Its water pressure in the site environment changes from 152.4 to 150.0 m and is higher than the water level of Lake Apvardai (143.5 m). The second aquitard (gt II md) occurs below.

A semi-confined aquifer (f II-III md-gr) with the thickness of up to 2 m and consisting of clayey sand occurs beneath the first aquitard. Its water pressure in the site environment changes from 152.4 to 150.0 m and is higher than the water level of Lake Apvardai (143.5 m). The second aquitard (gt II md) occurs below.

Characteristics of the aeration zone of the Apvardai site are as follows: thickness – 3.5 m, density – 2.2 g/cm^3, porosity – 0.25, effective diffusion coefficient – $1 \cdot 10^{-6}$cm^2/s, filtration coefficient – $1 \cdot 10^{-5}$cm/s (based on the existing laboratory measurements the filtration coefficient would be approximately $5 \cdot 10^{-6}$ cm/s; however, as future measurements are likely to show the increase of this value, we hereby suggest to conservatively assume that the filtration coefficient value is $1 \cdot 10^{-5}$ cm/s).

The aquifer of the Apvardai site has the following characteristics: thickness – 2.2 m, density – 2.2 g/cm^3, porosity – 0.3, filtration coefficient – $1.2 \cdot 10^{-3}$, gradient of water level (pressure) – 0.006 m/m; (Darcian) flow speed – $7.0 \cdot 10^{-6\ \mathrm{cm}}$/s.

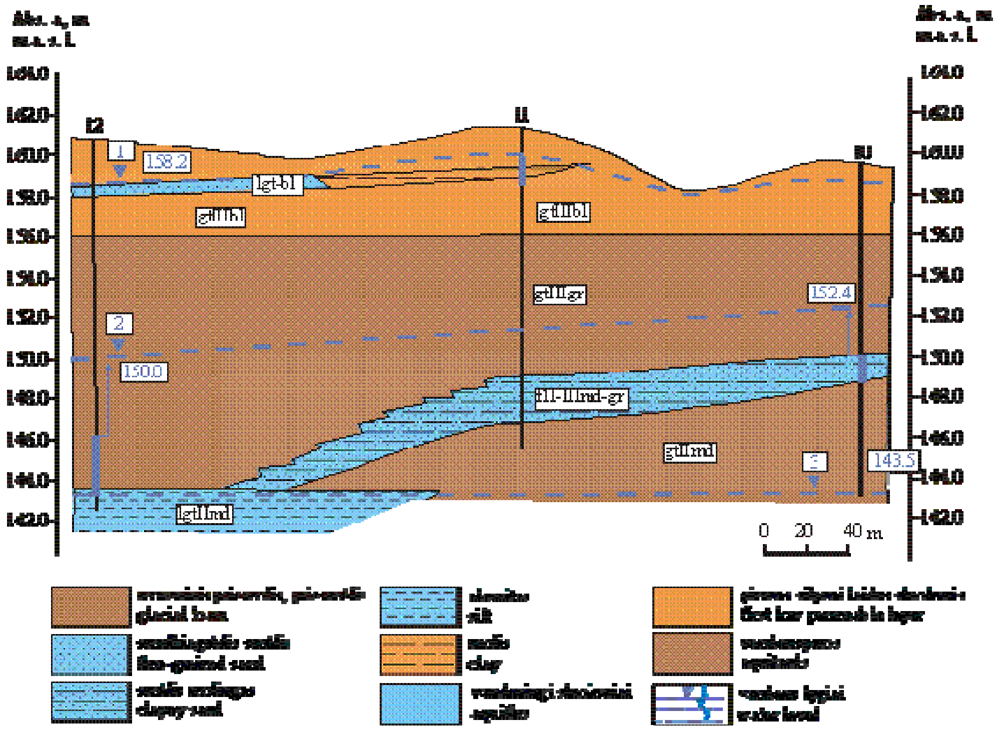
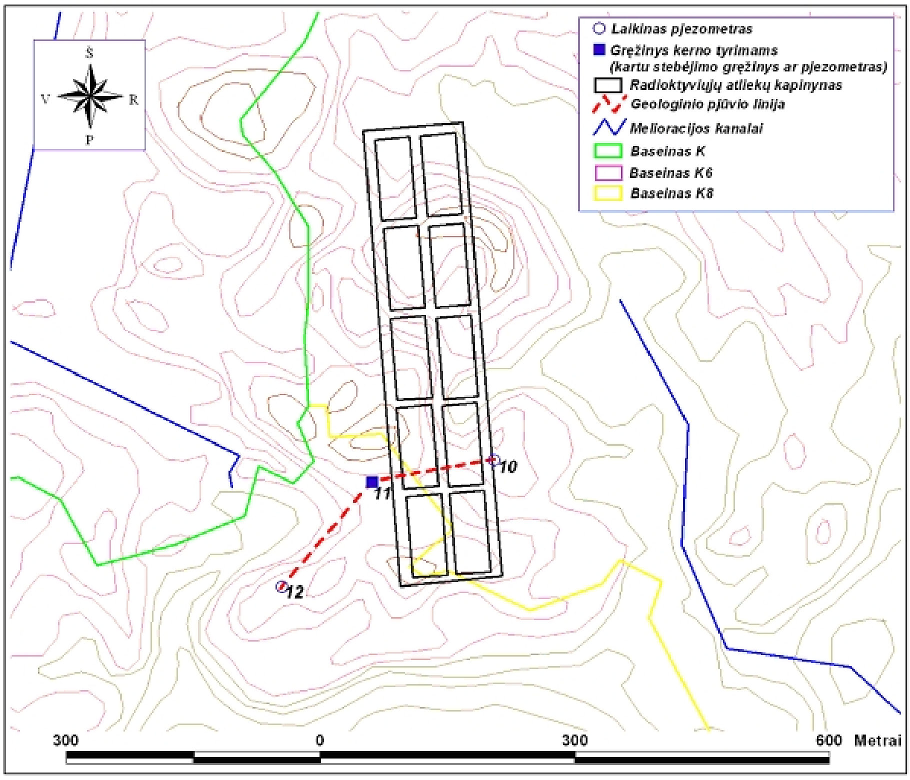


Fig. 4.1.1.7. Hydrogeological profile of the Apvardai site, adjusted according to the study data of 2003 and 2004. Water levels: 1 – groundwater, 2 – semi-confined aquifer, 3 – Lake Apvardai. The site of the hydrogeological profile is shown in Fig. 4.1.1.8.



Laikinas pjezometras	Temporary piezometer
Gręžinys kerno tyrimams (*kartu stebėjimo gręžinys ar pjezometras*)	A bore for the core tests (*at the same time – an observation bore or a piezometer*)
Radioaktyviųjų atliekų kapinynas	Radioactive waste depository
Geologinio pjūvio linija	Line of the geological profile
Melioracijos kanalai	Land reclamation canals
Baseinas K	Basin K
Baseinas K6	Basin K6

Baseinas K8	Basin K8
Metrai	Metres

Fig. 4.1.1.8. Test bores in the Apvardai site.

The water transfer path, which is important from the security point, is in the central part of the hill (vertical transfer is in till as in the aeration zone, and horizontal transfer is in semi-confined aquifer). Filtration coefficients are higher than in the Galilaukė site. The point of the discharge of the aquifer is the well (bore into groundwater) located 150 m away from the vaults of the repository, and Lake Apvardai located 1300 m to the southeast from the vaults of the repository.

Hydrochemical characteristics

Water sampled from surface water bodies and bores in the Apvardai site should be classified as calcium bicarbonate type of water. The bicarbonate content varies from 268.4 to 500.2 mg l. The bicarbonate content is twice as high in canal K-6, which is fed by underground water, than in canal K-8 (Table 4.1.1.16).

Table 4.1.1.16. Chemical composition of water in the Apvardai site on 6 July 2004

Place	**HCO3-**	**Cl-**	**SO42-**	**NO2-**	**NO3-**	**NH4+**	**Na++K+**	**Ca2+**	**Mg2+**	**B. solid**	**B. mineral**
	mg/l	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg-equiv/l**	**mg/l**
K-6	427.0	2.84	<2	0.050	0.357	0.671	0.77	99.64	25.22	7.06	558.55
K-8	268.4	0.85	9.8	0.060	0.344	0.806	0.00	69.31	22.65	5.33	372.22
Bore No. 11	500.2	14.20	23.0	0.077	0.419	0.979	32.79	102.52	32.22	7.78	706.41
Place	**BO**	**PO**	**N/NO2-**	**N/NO3-**	**N/NH4**	**Nmin.**	**Norg.**	**Nb.**	**Pb.**	**Pmin.**	**Porg.**
	mgO/l	**mgO/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**	**mg/l**
K-6	68.56	31.04	0.015	0.081	0.522	0.618	1.074	1.691	0.050	0.000	0.050
K-8	85.70	28.16	0.018	0.078	0.627	0.723	0.822	1.544	0.028	0.008	0.019
Bore No. 11	17.14	10.24	0.023	0.095	0.762	0.880	0.826	1.706	0.022	0.006	0.017

Streak groundwater from surface water bodies and bores in the Apvardai site should be classified as calcium bicarbonate type of water. It contains less biogenic and organic substances than in the Galilaukė site; however, with due consideration to the content of nitrogen and phosphorus compounds as well as the content of organic substance, water in surface water bodies and groundwater does not meet the requirements for drinking water as well.

The quality of drinking and domestic water must meet the requirements of HN 48:2001. There are no sources of quality drinking water in either Galilaukė or Apvardai site or in their vicinity. The closest source of water is the water extracting site of Visaginas, which is 5 km away from the Galilaukė site and 4 km away from the Apvardai site (by straight line). Local residents use water from shaft-wells for their needs; however, the quality of this water does not meet the requirements of HN 48:2001. On the other hand, there is often a shortage of this water during droughts. The demand for domestic water during the construction stage will be approximately 2 m³/day. Prior to the construction of a bore, this amount of water will have to be delivered from the water extracting site of Visaginas or from another source of water.

<u>STABATIŠKĖ SITE</u>

Hydrographical situation and characteristics of the flow

The Stabatiškė site is located 2-2.5 km south of Lake Drūkšiai. This site belongs to the direct basin of Lake Drūkšiai; there are no natural rivulets or lakes in the site. The hilly relief of Stabatiškė is divided by hollows that are either permanently or seasonally flooded (Fig. 4.1.1.9). Shallow low-lying swampy lands have been formed in some hollows. Hills situated in the site were previously used in agriculture, while lower lands were overgrown with forest. In the outskirts of the site, between the hills and roads surrounding the site, there are many swampy hollows or almost fully overgrown small lakes that are permanently or temporarily present as a result of bad drainage conditions and that were formed following the replacement or destruction of the former drainage system, also as a result of beaver dams. Surplus water flows from wetlands to Lake Drūkšiai by land reclamation canals.

Domestic waste are directed by pipes from the Ignalina NPP to the purifying plant of Visaginas situated at Lake Skripkai (south of the Stabatiškė site); the wastewater pipeline runs along the western edge of the site. Treated wastewater is released to Lake Drūkšiai via the Gulbinėlė rivulet.

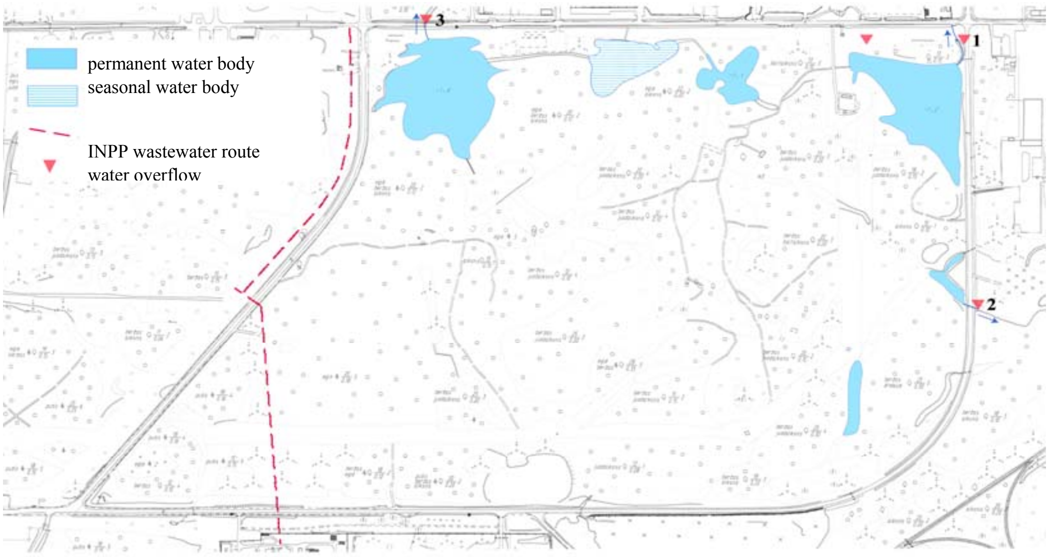


Fig. 4.1.1.9. Hydrography and hydraulic installations of the Stabatiškė site

Canals that drain the Stabatiškė site and its neighbouring areas have been directed to Lake Drūkšiai. Two of the canals (Fig. 4.1.1.9, points 1 and 3) run from the site by the closed drainage system of the Ignalina NPP, and they surface only right before they reach the lake.

The hydrographical network of the Stabatiškė site and its environs has been mostly changed during the construction of the Ignalina NPP. The drainage adapted for agrarian activities in an almost natural relief has been destroyed as a result of the construction of road beds blocking the flow, the levelling of lowlands that served as a natural drainage, etc. Hollows in the site are seasonally flooded, and slack water bodies are formed as a result of bad run-off conditions. The site has hills (relative height: 5-7 m) that surround the low-lying swampy land overgrown with trees and bushes; water flows from this swampy land along the ditch that is frequently dammed by beavers. Down the flow, water enters into hollows located in the south-eastern part of the site, and then flows to the southeast along the canal (Fig. 4.1.1.9, point 2).

The northern part of the site is being drained by a ditch (which is dammed in several places by beavers) along which water flows to the east from flooded hollows. A small lake has been formed on the north-western edge of the site as a result of changes in the drainage system; when the water level is high, the area of this lake is 4.35 ha, while it reduces in size almost twice during droughts. Water flows from this small lake along the ditch to two even smaller lakes: the first lake is temporary, as it dries up during droughts, while the area of the second lake is 0.88 ha (when the water level is high). When the water level is high, some water flows from the northern edge of the Stabatiškė site over the road overflow (Fig. 4.1.1.9, point 3). There is no flow in these drainage systems for the better part of the year; water flow occurs only during spring floods and rain high water (for approximately two months). In 2005-2006, the highest flow (0.9 l/s) was registered in point 3 (Table 4.1.15).

A small lake has also been formed in the hollow located on the north-eastern edge of the site and dammed by the road bed from the east. When the water level is high, its area is 3.25 ha. Water flows from the small lake to the north by a closed drainage system (Figure 4.1.1.9, point 1); it interflows with other canals that drain the territory of the Ignalina NPP and pipes of the closed drainage system, and enters Lake Drūkšiai at the mouth of the discharge pipe. The flow of rate at the point of outflow of the small lake evaluated in 2005-2006 ranges from 0.005 to 18.6 l/s (Table 4.1.15).

The northern part of the Stabatiškė site is drained by ditch S-1 that flows water to the east. As a result of previous changes of the drainage system made during the construction of the Ignalina NPP, three permanent and one seasonal small lake have been formed on this edge of the site (Fig. 4.1.1.9). The water regime in ditch S-1 has also been changed by dams constructed in several places by beavers. From ditch S-1 the largest part of the flow enters a small lake located in the northeast of the site, and then flows from there to the north by underground drainage canals (d 1200). However, the surplus water from the north-western part of the site flows along this canal very slowly as a result of small slopes and beaver dams. Therefore, a road overflow has been constructed in the north-western part of the site (approximately 100 m from the crossroad to the Ignalina NPP; Fig. 4.1.1.9, point 3).

The central, eastern and south-eastern part of the site is drained by sinks in the area among hills that feature shallow ditches in some places. Huge areas of wetlands have been formed in hollows as a result of toad beds constructed in the east and southeast, changes of the drainage system made in the power line route, and beaver dams. Water from there flows into the land reclamation canal crossing the road located to the east from the site (Fig. 4.1.1.9, point 2). The variation of the flow of the canal is very high due to very complicated and technogenically changed flow conditions of this part of the site.

The central and south-eastern part of the site is drained by a ditch stretching from northwest to southeast (Fig. 4.1.1.9, point 2) and flowing water to Šaškai bay of Lake Drūkšiai. It collects surplus water from the majority of wetland surrounding the site as well. The rate of flow measured in 2005-2006 ranged from 0.1 to 35.4 l/s (Table 4.1.1.15); however, after the rainfall on 12 May 2005 amounted to <1% probability of daily rainfall, the measured rate of flow was as high as 150 l/s.

Table 4.1.1.15. Rate of flow of the Stabatiškė site measured on 26 July 2005 – 12 May 2006

Statistical indicators	**Rate of flow, l/s**		
	Point 1	**Point 2**	**Point 3**
Minimum	0.05	0.1	0
Maximum	18.6	35.4	0.9
Average	1.75	2.71	0.52

The calculation of the water balance of the Stabatiškė site is based on short-term observation of the rate of flow in the site (July 2005 – May 2006), observations of the Dūkštas meteorological station (1971-2005), and statistical indicators describing the water balance of the region (*Gailiušis ir kt.,* 2001). It has been established that the major part (515 mm) of precipitation (the annual average for the location: 700 mm) is used for evaporation. The evaporation indicator may further increase after the assessment of major wetlands located in the site and its vicinity. The surface and soil (drained within the contour of the site) run-off is 162 mm. The remaining run-off is drained groundwater and deep infiltration (Fig. 4.1.1.10).

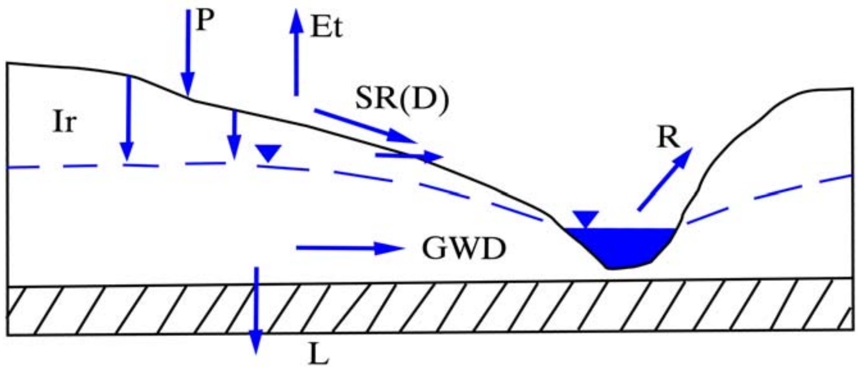


Fig. 4.1.1.10. Scheme of the water balance of the Stabatiškė site: P – atmospheric precipitation, ET – evaporation, SR – surface run-off, GWR – groundwater run-off to rivers and drains, L – crossover, and R – outflow. (**P** = 700 mm, **Et** = 515 mm, **SR(D)** = **R** = 162 mm, **GWD+L** = 23 mm).

Land reclamation system

There are no accurate data about land reclamation in the Stabatiškė site; however, ditches that remain in the area among hills allow us to conclude that a drainage system has been installed here once.

Nature and condition of hydraulic installations

A new drainage system was installed during the construction of the Ignalina NPP, which largely consisted of underground drainage. In some places former surface land reclamation canals have been replaced with large-diameter drainage pipes. In some places the direction of flow of canals has been changed. A reinforced concrete pipe overflow (d 600) has been constructed under the road in the north-western part of the site, approximately 100 m to the east from the crossroad to the Ignalina NPP; the overflow is relatively high above the bottom of ditch S-1 (Fig. 4.1.1.9). This overflow is only used by water resulting from spring floods and heavy rainfall. A reinforced concrete pipe overflow (d 1200) has been constructed under the road in the north-eastern corner of the site; it flows approximately 70% of the run-off from the northern section of the site to the underground drainage system.

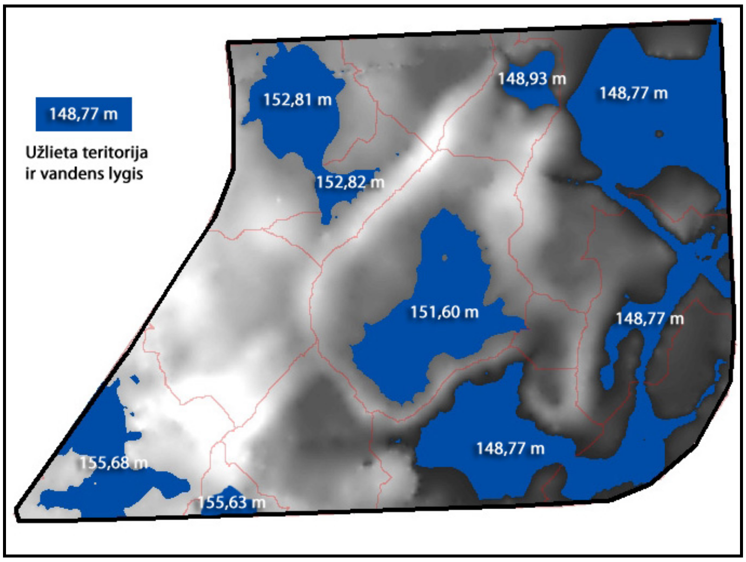
A reinforced concrete pipe overflow (d 1200) has been constructed under the road on the eastern edge of the site, which flows water from the central, south-eastern and eastern section of the site. Wetlands formed above the overflow show that incorrect assessment of the conditions of the run-off in this territory was made during the construction of this overflow.

Potential flooding of the site

The analysis of the fluctuations of the water level in Lake Drūkšiai and geomorphologic conditions of the basin at the point of outflow of the lake and its vicinity established (*Mažeika, Paviršinio..., 2006)* that hydrodynamic processes in Lake Drūkšiai cannot cause the flooding of the territory of the Stabatiškė site.

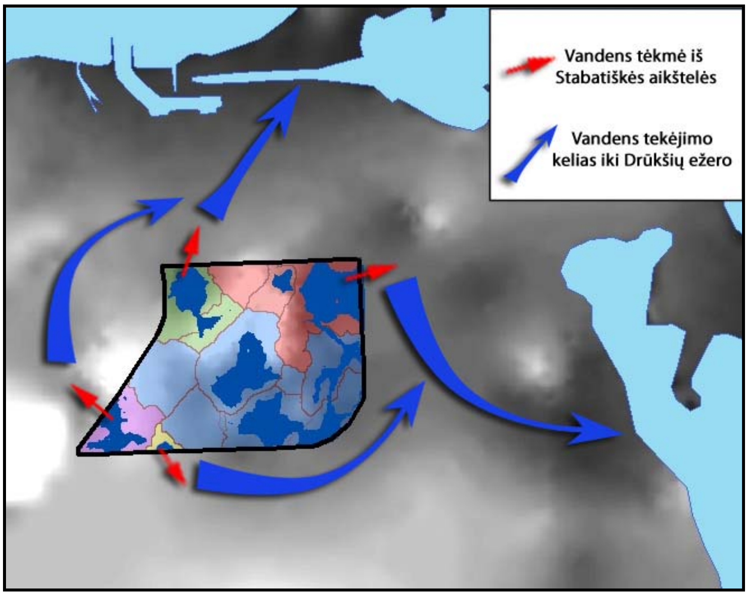
The following three extremely conservative assumption were made during further analysis of the potential flooding of the Stabatiškė site caused by heavy precipitation in the site: 1) heavy precipitation (exceeding maximum precipitation amounts of 1961-2004); 2) sudden melting of snow; 3) complete blocking of water overflows. The assessment did not consider the reduction of water resources as a result of evaporation, infiltration and run-off. Based on the results of the analysis of the digital model of the surface of the Stabatiškė site and its vicinity, also on the assumption that the foundation of the repository will be constructed in the level of 154 m and 153.5 m in the western hill and eastern hill respectively (*Rimidis, 2005*), it has been established that under maximum flooding conditions the difference between the altitudes of the surface of water and the repository foundation shall be 1.18 m and 1.80 m respectively (Fig. 4.1.1.11). Thus, under no circumstances the territory of the Stabatiškė site can be flooded; however, in this case engineering barriers that eliminate the capillary rise of groundwater, viz. broken stone and puddle clay layers (*Rimidis, 2005*), are a must (*Mažeika, Paviršinio..., 2006*).

The maximum backwater of the Stabatiškė site would be achieved if at least 183 mm precipitation would fall in the territory during the hypothetically short period. Based on the 1961-2004 observation data, only the accumulated precipitation that fell during a long period (30 days) exceeded 183 mm twice in 43 years. Thus, under extremely conservative assumptions, the maximum backwater of the Stabatiškė site would be achieved only once in 20 years, which is shown in Fig. 4.1.1.11. If the maximum backwater is achieved and in the present of hypothetical precipitation of any intensity, the surplus water shall flow from the Stabatiškė site over the road bed to the neighbouring territory, and then to Lake Drūkšiai along the descent of the relief (Fig. 4.1.1.12). The relief of the Stabatiškė site and its vicinity determines that backwater reaching the height of the foundation of the planned repositories cannot be formed under natural conditions. Maximally flooded areas are determined by the heights of road beds surrounding the site and natural overflows of isolated sub-basins (*Mažeika, Paviršinio..., 2006*).



Užlieta teritorija ir vandens lygis	Flooded area and the level of water

Fig. 4.1.1.11. The area of the Stabatiškė site that is maximally flooded by water (situation when any surplus water flows over the road bed to Lake Drūkšiai).



Vandens tėkmė iš Stabatiškės aikštelės	Flow of water from the Stabatiškė site
Vandens tekėjimo kelias iki Drūkšių ežero	Path of water flow to lake Drūkšiai

Fig. 4.1.1.12. Water flow from the Stabatiškė site under maximum backwater, and the path of water flow to lake Drūkšiai.

Water consumers

There are no consumers of surface or groundwater in the Stabatiškė site. Prior to the construction of the Ignalina NPP there were four homesteads that took water from shaft-wells. One well has survived; it is located in the northern section of the site, and it is not in use. The nearest groundwater wells in use are located in villages surrounding the Galilaukė site.

Data on underground water extracting sites located within the radius of 15 km from the Stabatiškė site are provided in Table 4.1.1.16. This area has 5 underground water bodies marked in the state registry. Visaginas City and the Ignalina NPP are the major consumers of underground water; together they consume almost 9,000 m^3 water (extracted from the Visaginas water extracting site) per day. Generally speaking, there are quite a few isolated underground water extracting bores in the area of the Stabatiškė sites owned by different owners (Table 4.1.1.17).

Table 4.1.1.16. Information about underground water extracting sites within the radius of 15 km from the Stabatiškė site (in the territory of Lithuania)

Address	**Code of the body**	**Location**		**Index of the aquifer used**	**Average amount of extracted water, m^3/day, based on the data of 2002-2005**
		X	**Y**		
Visaginas City, Visaginas Municipality, Utena County	113	6163393	658771	D_3šv+D_2up	8743
Kimbartiškė Village, Turmantas Neighbourhood, Zarasai Region Municipality, Utena County	2691	6174403	657050	agII	11
Bartkiškė I Village, Turmantas Neighbourhood, Zarasai Region Municipality, Utena County	2693	6176045	653634	agI	15
Turmantas Railway Station,	2984	6176733	655063	D_3šv+D_2up	1

Turmantas Neighbourhood, Zarasai Region Municipality, Utena County					
Rimšė Town, Rimšė Neighbourhood, Ignalina Region Municipality, Utena County	3338	6156733	654584	agIII	9

Table 4.1.1.17. More detail information about underground water extracting bores in operation within the radius of 15 km from the Stabatiškė site (in the territory of Lithuania)

Address	**Location**		**Bore No.**	**Index of the aquifer used**	**Depth of the bore, m**	**Bore owned by**
	X	**Y**				
Tilžė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6172368	662739	5454	D_2up - D_3šv	130	NEIGHBOURHOOD
Tilžė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6172308	662776	5455	D_2up - D_3šv	122	NEIGHBOURHOOD
Turmantas Town, Turmantas Neighbourhood, Zarasai Region Municipality	6175546	655679	8030	D_2up - D_3šv	170	NEIGHBOURHOOD
Kimbartiškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6171251	659315	12770	Q	95	NEIGHBOURHOOD
Kimbartiškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6174884	657084	12789	gQ_2 - gQ_3	52	NEIGHBOURHOOD
Paukšteliškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6170881	648828	12805	Q	114	NEIGHBOURHOOD
Tilžė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6173906	657417	13701	gQ_2žm	115	NEIGHBOURHOOD
Gerkoniai Village, Dūkštas Neighbourhood, Ignalina Region Municipality	6160045	650513	13715	S_2	337.5	NEIGHBOURHOOD
Antalgė Village, Rimšė Neighbourhood, Ignalina Region Municipality	6158473	654253	13717	gQ_3vr	50	NEIGHBOURHOOD
Beržininkai II Village, Rimšė Neighbourhood, Ignalina Region Municipality	6161014	662040	13720	fQ_2žm - fQ_3vr	72	NEIGHBOURHOOD
Nagėnai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6156263	655648	13802	Q	73	NEIGHBOURHOOD
Beržininkai II Village, Rimšė Neighbourhood, Ignalina Region Municipality	6160201	661824	13803	Q	41	NEIGHBOURHOOD
Rimšė Town, Rimšė Neighbourhood, Ignalina Region Municipality	6156203	653946	13879	gQ_2vrs	42	NEIGHBOURHOOD
Gaidė Village, Rimšė	6161146	660579	13880	gQ_2vrs	62	NEIGHBOURHOOD

Address	Location		Bore No.	Index of the aquifer used	Depth of the bore, m	Bore owned by
	X	Y				
Neighbourhood, Ignalina Region Municipality						
Kimbartiškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6174423	657171	13891	D_2up - D_3šv	120	NEIGHBOURHOOD
Bieniūnai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6158118	655582	13941	Q	93	NEIGHBOURHOOD
Žibakiai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6158193	657685	13942	Q	35	NEIGHBOURHOOD
Bartkiškė I Village, Turmantas Neighbourhood, Zarasai Region Municipality	6175484	653950	14087	D_2up	150	NEIGHBOURHOOD
Čepukiškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6174669	650989	14088	D_2up - D_3šv	135	NEIGHBOURHOOD
Rimšė Town, Rimšė Neighbourhood, Ignalina Region Municipality	6157348	653941	19048	aglQ_3vr-gr	45	NEIGHBOURHOOD
Padabinka Village, Turmantas Neighbourhood, Zarasai Region Municipality	6172807	650861	19151	D_3šv	116	NEIGHBOURHOOD
Kamariškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6174809	654988	19152	D_3šv	153	NEIGHBOURHOOD
Egliniai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6158044	653478	19156	gQ_3vld	30	NEIGHBOURHOOD
Smalvos Village, Turmantas Neighbourhood, Zarasai Region Municipality	6170184	648362	19363	D_2up - D_3šv	130	NEIGHBOURHOOD
Bartkiškė I Village, Turmantas Neighbourhood, Zarasai Region Municipality	6176065	653755	19369	D_3šv	118	NEIGHBOURHOOD
Bartkiškė I Village, Turmantas Neighbourhood, Zarasai Region Municipality	6176125	653700	19370	D_3šv	132	NEIGHBOURHOOD
Šakiai Village, Turmantas Neighbourhood, Zarasai Region Municipality	6172125	658671	19373	D_3šv	145	NEIGHBOURHOOD
Paukšteliškė Village, Turmantas Neighbourhood, Zarasai Region Municipality	6170991	649332	20059	D_2up - D_3šv	125	NEIGHBOURHOOD
Bieniūnai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6158251	656718	20639	gQ_1dz	100	NEIGHBOURHOOD
Turmantas Town, Turmantas Neighbourhood,	6176732	655063	27880	D_2sto	132	LITHUANIAN RAILWAYS

Address	Location		Bore No.	Index of the aquifer used	Depth of the bore, m	Bore owned by
	X	Y				
Zarasai Region Municipality						
Visaginas City, Visaginas Municipality	6162802	658437	29658	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Karlai Village, Visaginas Municipality	6164410	656272	30857	D_2up - D_3šv	128	BOARDING-HOUSE OF VISAGINAS
Visaginas City, Visaginas Municipality	6162851	658593	30960	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6163161	658593	30962	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6163761	658669	30964	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6162818	658438	30965	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6164084	658675	30966	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6164231	658666	30968	D_3šv - D_2up	165	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6164150	658822	30975	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6164263	658945	30976	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6163715	658504	30977	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6162960	658357	30978	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6162245	658474	30979	D_3šv - D_2up	172.5	STATE ENTERPRISE IGNALINA NPP
Energetikų Street, Visaginas City, Visaginas Municipality	6163928	654398	31053	lgIIIbl	19	NIKOLAJ GOLOSKOKOV
Visaginas City, Visaginas Municipality	6164253	658765	31120	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Visaginas City, Visaginas Municipality	6163902	659043	31121	D_3šv - D_2up	175	STATE ENTERPRISE IGNALINA NPP
Rimšė Town, Rimšė Neighbourhood, Ignalina Region Municipality	6156733	654584	34235	gIIžm	51	UAB *ARGINTA*
Ramybė Village, Visaginas Municipality	6163059	651428	36120	D_2up	128	STATE ENTERPRISE IGNALINA NPP
Čeberakai Village, Visaginas Municipality	6163385	658824	38091	D_2up - D_3šv	175	STATE ENTERPRISE *VISAGINO*

Address	Location		Bore No.	Index of the aquifer used	Depth of the bore, m	Bore owned by
	X	Y				
						ENERGIJA
Čeberakai Village, Visaginas Municipality	6162896	658868	38092	D_2up - D_3šv	175	STATE ENTERPRISE *VISAGINO ENERGIJA*
Vėlūnai Village, Rimšė Neighbourhood, Ignalina Region Municipality	6154086	658369	38727	fIIžm-md	49	REGINA GLEBAVIČIENĖ
Lapušiškė Village, Visaginas Municipality	6161871	652552	38861	D_2up - D_3šv	162	*PAVASARIS* GARDENERS' COMMUNITY
Lapušiškė Village, Visaginas Municipality	6162191	652983	38862	D_2up - D_3šv	162	*PAVASARIS* GARDENERS' COMMUNITY

There are approximately 10-15 underground water extracting bores in the localities of Drisviaty, Dvorishchia, Miliuntsy and Grituny in Belarus, some 15 km away from the Stabatiškė site. Even though less underground water extracting sites in operation have been counted in the zone of the same radius in Belarus, it could be assumed that here the rate of flow of bores intended for major agricultural companies should be slightly higher than of isolated bores operated in Lithuania and not related to agricultural companies.

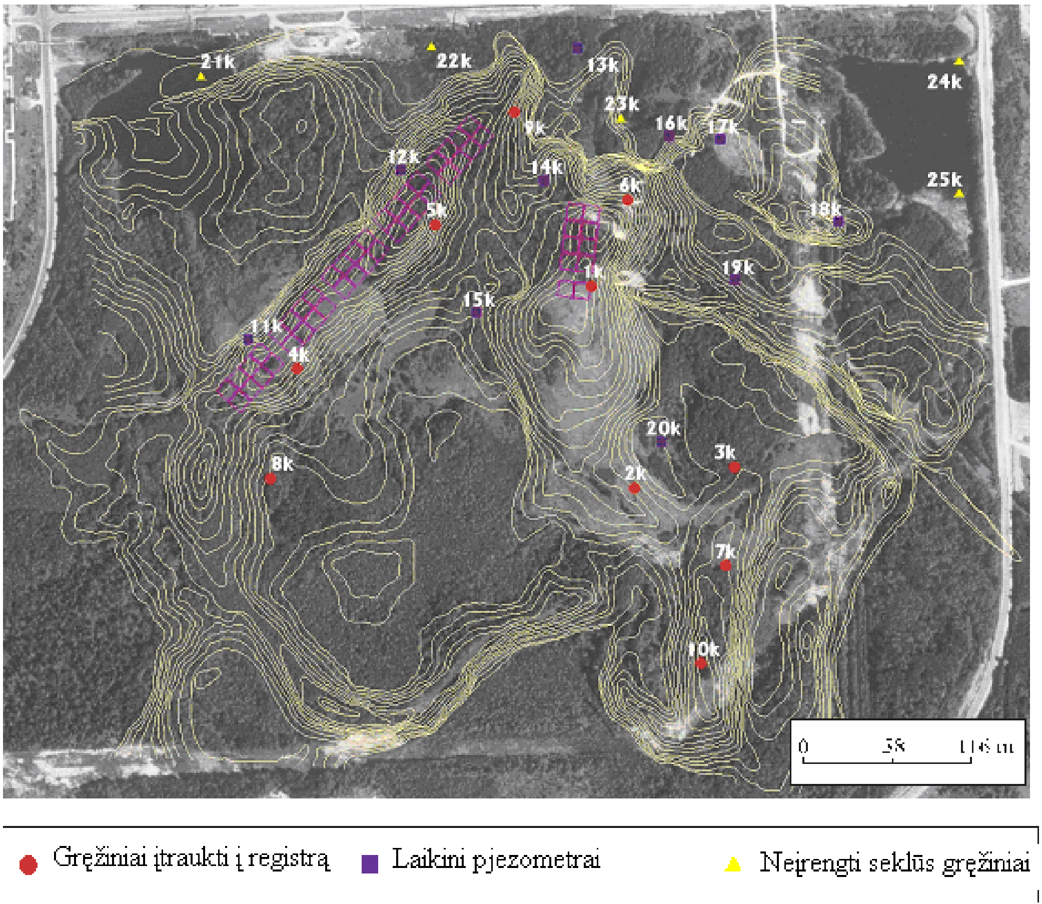
Hydrogeological conditions

During studies carried out in 2005-2006 two aquifers were identified in the territory of the Stabatiškė site, in the depth up to 20-30 m (*Laikinųjų pjezometrų..., 2005; Račkauskas, Janulevičius, Abromavičiūtė, 2005; Račkauskas, Janulevičius, Abromavičiūtė, 2006*): 1) the upper aquifer: groundwater (and/or water above streak); 2) the lower aquifer: middle (and in some places – confined) water.

Groundwater (the first from the surface of the earth; unconfined) accumulates in peat, sand and soil layers and in streaks existing in glacial loam and clay loam, also in interlayers or more permeable zones. In lower relief areas groundwater is continuously present through the year, while in the highest places the presence of upper groundwater is seasonal. In shallow piezometers installed at deep bores the level of groundwater was measured in sites of all bores in spring. Thus, it could be stated that there are two types of groundwater in the territory: 1) continuously present (in lower sections of the relief); 2) seasonally present (in the highest relief areas, viz. hills).

In the lowest relief areas, groundwater level was detected up to the several dozen centimetres deep from the surface of the earth. The highest altitude of the level of underground middle water in the eastern hill of the Stabatiškė site is 149.70 m above the sea level in bore 2k (Fig. 4.1.1.13). The highest altitude of sporadic groundwater near the hills is 152.5 m in bore 14k. The intended altitude of repository vaults is 154.0 and 153.5 m. After the formation of impermeable barriers over the repository, the groundwater level should further decrease a little, as the infiltration recharge will be minimally reduced and drainage conditions will be improved. The level of underground middle water will remain almost unchanged for a very long period.

By altitude, the highest level of groundwater is in hills. Form there, water flows downwards towards ravines and swampy areas. Around the hills the direction of groundwater is most frequently of a radial nature, i.e. it flows down the hill in all directions. However, the general inclination of the relief of the site is towards the northeast (towards lake Drūkšiai); it is in this direction that the flow of surface water and underground water is formed. Some profiles of the site show that groundwater and surface water (swamps, puddles) is hydraulically closely connected in lower areas. The altitude of the level of water in the north-eastern pond (bores 24k and 25k) is almost 4 metre lower than the altitude of the level of water in the north-western pond (bore 21k). In many places the site is covered with clayey rocks, i.e. rocks with low water permeability (Table 4.1.1.18).



Gręžiniai įtraukti į registrą	Bores entered into the registry
Laikini pjezometrai	Temporary piezometers
Neįrengti seklūs gręžiniai	Shallow bores, not equipped

Fig. 4.1.1.13. Bores in the Stabatiškė site

Table 4.1.1.18. Data on filtration characteristics of low permeable rocks of the Stabatiškė site

Bore No.	**Coordinates of the bore**	**Depth or interval of sampling, m**	**Density of rock, g/cm^3**		**Porosity, %**	**Filtration coefficient, m/day**	**Filtration coefficient, m/s**
			saturated	**dry**			
1k	662064 6165236	1	2.38	2.10	0.28	$7.6 \cdot 10^{-3}$	8.8E-08
		1	2.41	2.12	0.29	$7.9 \cdot 10^{-3}$	9.1E-08
2k	662123 6164988	1	2.44	2.14	0.3	$8.2 \cdot 10^{-3}$	9.5E-08
		1	2.40	2.12	0.28	$7.7 \cdot 10^{-3}$	8.9E-08
		1	2.41	2.10	0.31	$8.0 \cdot 10^{-3}$	9.3E-08

More permeable sediments (peat, sand) are sporadically present. Their filtration coefficient is assumed to be higher by one row. Therefore, the average speed of the groundwater flow should also be very low – up to several centimetres per day.

The second aquifer from the surface of the earth occurs between two water impermeable clayey layers in the investigated territory. Aqua glacial sediments (varigrained sand, gravel and sand, dusty sand, gravel) of the Upper Pleistocene Grūda sub-suite – Middle Pleistocene Medininkai suite of the Quaternary thickening are water permeable from the geological point of view. During the investigation period, the level of ***middle underground water*** was 4.32-11.71 m below the surface of the earth or 147-148 m above the Baltic sea level. The level of water of this aquifer is the deepest from the surface of the earth in hills, and the shallowest – in the lowlands (Fig. 4.1.1.14). In major area of the territory water is unconfined – its level coincides with the top of the sandy layer in places. In lower places (bores 8k and 9k) water is confined, i.e. its piezometric level rises in bores from several dozen centimetres to several metres above the top of the layer (*Mažeika, Vandens…, 2006*).

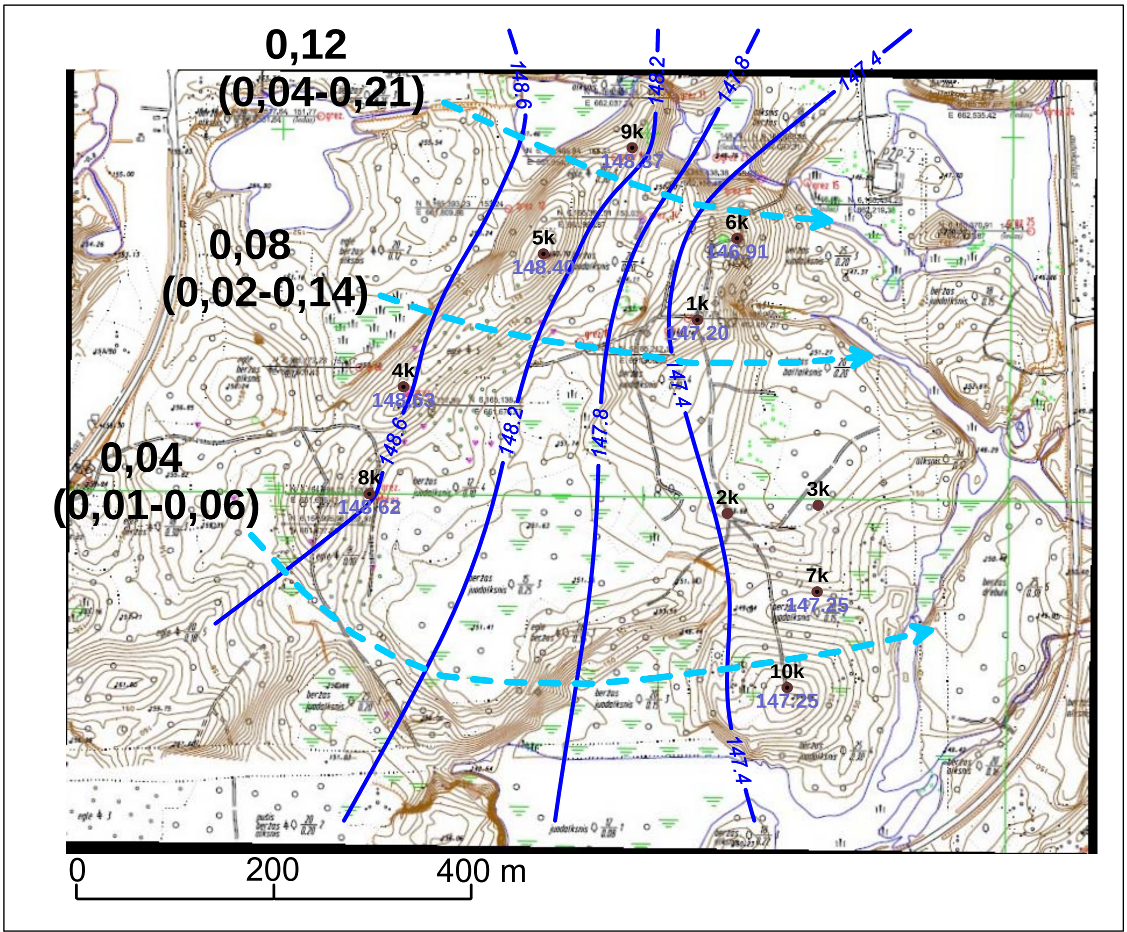


Fig. 4.1.1.14. Average altitudes of the underground water level in the Stabatiškė site (numbers provided at the bores are equivalent to the median for the total investigation period, m a.s.l.), the hydro isopiez distribution (continuous lines, m a.s.l.), water flow directions (arrows) and Darcian speed (median values and the interval of change, m/day).

Altitudes of the middle water level sink towards the pond located in the north-eastern part of the territory and towards lake Drūkšiai located further. The direction of underground water coincides with the direction of sinking of the altitude of the water level (Fig. 4.1.1.14). Underground water is discharged into lake Drūkšiai. As several dozen years-old aerophotographs do not show any surface water body in the north-eastern territory, the surface water of the pond formed during the construction of the Ignalina NPP and middle underground water do not have any hydraulic connection. Based on geological profiles, it could be assumed (bores 24k and 25k) that the surface water of the pond and middle underground water are separated by a sever meter-thick layer of the low water permeable till.

Based on the results of the analysis of the mechanical composition of soil (granulometric analysis), the filtration coefficient of the rocks of the aquifer changes from 4.6 to 27.2 m/day. Short-term water tests of three bores (4k, 6k and 7k) showed that filtration coefficients could even be higher (*Račkauskas, Janulevičius, Abromavičiūtė, 2006*). Bore filters have been installed in visually most permeable zones (in coarse-grained sand and gravel). The filtration coefficient values of the layer obtained using different methods are presented in Table 4.1.1.18. The generalised average filtration coefficient of the rocks of the aquifer is approximately 19 m/day. As the layer consists of varigrained sandy sediments, the filtration coefficient changes vertically as well as horizontally.

The main aquifer is restricted from below by the till and glacial loam (brown, rigidly or softly plastic) of Medininkai suite, which may be a partial aquitard from the hydrodynamic point of view. In the northern part of the territory (bores 5k and 6k), low permeable layers of clay and silt occur above the glacial till of Medininkai suite, which also reinforce the aquitard characteristics.

Table 4.1.1.18. Filtration coefficients of the rocks of the intermoraine aquifer

Bore No.	**Filtration K based on the results of the mechanical analysis of soil, m/day (*the interval of sampling, m, is provided in brackets*)**		**Filtration K based on the results of the water test of bores, m/day**		**Average, m/day**
			According to the marking of the water level	**According to the rise of the water level**	
4k	6.93 *(11.7-11.9)*	4.56 *(17.0-17.5)*	11.5	11.04	8.5
6k	27.2 *(13.0-14.0)*	20.5 *(16.2-16.7)*	30.6	49.2	31.8
7k	16.3 *(13.0-13.5)*	11.3 *(15.5-16.0)*	14.6	20.0	15.5
Average, m/day	16.8	12.1	18.9	26.7	**18.6**

The aquifer of aqua glacial sediments of the Middle Pleistocene Žemaitija-Dainava suits (sand) occurs under the glacial till of Medininkai suite. Bores were drilled only 0.8-1.2 m into it. Neither pressure nor hydraulic connection with an upper layer has been established.

Model calculations have been performed to assess the flows of underground water, using the FEFLOW code (*Mažeika, Vandens...., 2006*). Results are provided in Fig. 4.1.1.15. The results of calculations how that underground water empties to lake Drūkšiai.

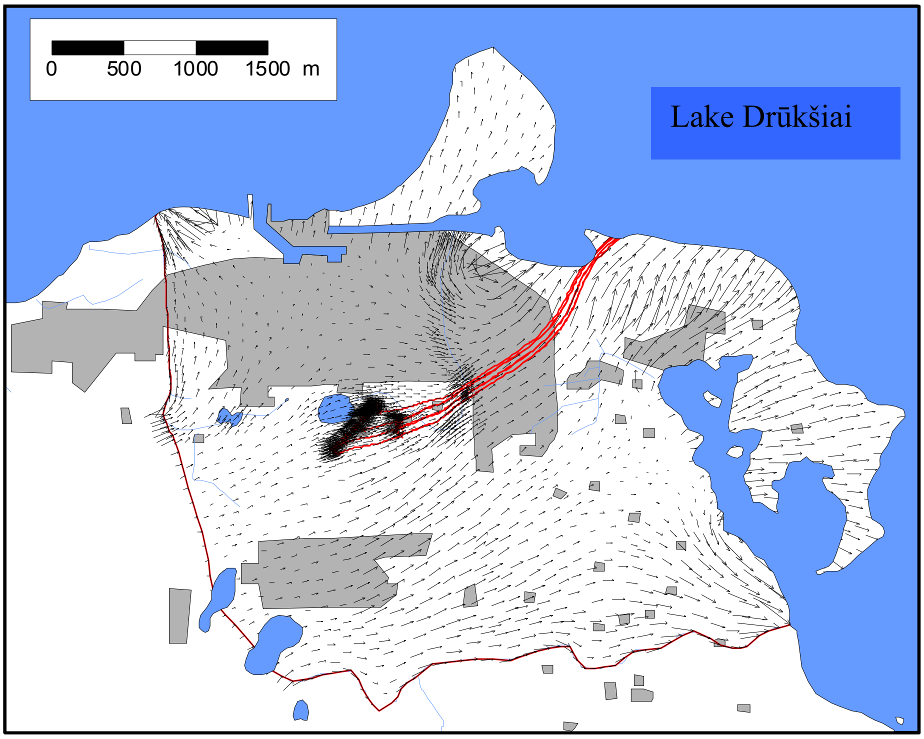


Fig. 4.1.1.15. Directions of flows of underground water of the main aquifer in the Stabatiškė site simulated using the FEFLOW code (the lines of flows from the repository site are marked in red)

The speed of the infiltration recharge has been assessed according to the profile of the vertical distribution of tritium. In the monitored bores analysed in 2006, the activity of ^{3}H in water in the Stabatiškė site changed from 5.4 to 15.4 TV (the annual average in precipitation water was approximately 9 TV). The lowest activity was measured in water of bore 9. This indicates a slower infiltration of water.

In 2006, the distribution of the activity of ^{3}H in the humidity of the aeration zone was analysed in one profile in the Stabatiškė site. The concentration of ^{3}H in the humidity of the rocks of bore 5 changed from 33.8 TV to the detection limit (2-3 TV). The PFM (*piston flow model*) model was used for the assessment of the distribution of ^{3}H in the vertical profile and the speed of circulation of humidity in the aeration zone (using the TRACER code). With the multiannual change of activities of ^{3}H in precipitation known, the function (of a certain probability) of the hydrological system of the activities of ^{3}H in water and of the "age" of that water is established. The results of calculations are further specified in Table 4.1.1.19.

Table 4.1.1.19. The values of the vertical infiltration speed (u_{in}) and the infiltration flow (q_{in}) established according to the data of tritium and volumetric moisture content of the aeration zone (alpha – 0.6).

Bore No.	**Coordinates of the bore**	**Water flow path ΔL, m**	**Water flow time tt, year**	**Average volumetric moisture content, %**	**Infiltration amounts***		
					Vertical speed u_{in}, mm/year	**Infiltration flow q_{in}, mm/year**	**Infiltration flow q_{in}, $m^3/m^2 \cdot$year**
5	6165325 661854	6.0	53	0.30	113	**20**	0.020

The infiltration flow in the western hill is approximately 20 mm/year, considering the integral assessment of all thickening down to the underground water level. The infiltration flow is higher in the upper part of the glacial loam (some of the flow will run off laterally), as surface ground water accumulates on the clay loam on a seasonal basis, the level of which */text is missing, - translator's note/* through the year.

Hydrochemical characteristics

The results of the quality analysis of underground and surface water are provided in the thesis (*Račkauskas, Janulevičius, Abromavičiūtė, 2006*), while the results of the general chemical analysis are summarised in Table 4.1.1.20. The chemical composition of middle water (bores 4k to 10k), groundwater (bores 12k to 20 k) and surface water (ponds and the rivulet) is similar. Water is either fresh or slightly mineralised, calcium bicarbonate. Its mineralisation (the sum of dissolved mineral substances) is from 493 to 1223 mg/l.

Based on many indicators, the quality of water meets the requirements of the said standard. In some cases the quantity of permanganate of groundwater (bores 16k and 20k) and surface water (bores 13k, 21k and 24K) slightly exceeds MAC (*Higienos norma HN 48:2001, 2001*). The quantity of permanganate indirectly indicates the content of the organic substance in water. The organic substance contained in groundwater and surface water of the Stabatiškė site is mostly of a natural origin. Higher concentrations of nitrites (NO_2^-) and ammonium (NH_4^+) have been established in some places (bore 12k, the pond, the rivulet near bores 13k and 24k). As in the case regarding the quantity of permanganate, this can also be related to the decay of the natural organic substance (that is abundant in the swampy locality). However, the higher values of the said components may also be influenced by fractures of the sewerage pipeline of the Ignalina NPP built in the south-western part of the Stabatiškė site.

Based on the results of the analysis of trace elements (heavy metals), iron and manganese concentrations exceeded the MAC (as provided by the said Hygiene Standard) in surface water and groundwater in some places (bore 20k, ponds near bores 21k and 24k). It is also related to the abundance of the organic substance and its transformations in the swampy environment.

During observation, rather high biogenetic concentrations have been established in some surface water bodies and bores (Table 5). Having entered surface water bodies, water of such quality stimulates eutrophication processes. With due consideration to the requirements applicable to the quality of river water defined by maximum authorised concentrations of priority and hazardous substances approved by Order No. 623 *On the Approval of Rules for the Reduction of Water Pollution with Priority Hazardous Substances* of the Minister of Environment and by Order No. 267 *On the Partial Amendment of Some Orders of the Minister Regulating Wastewater Management* of the Minister of Environment, the concentration of phosphorus, nitrogen or compounds thereof exceeded the maximum authorised concentration in many water samples (Table 4.1.1.21).

Table 4.1.1.20. Summary of the results of the general chemical analysis

Bore No.	Cl	SO_4	HCO_3	NO_2	NO_3	Na	K	Ca	Mg	NH_4	Total hardness	BM*	PS*	pH	ChDS*	SiO_2	CO_2 (aggressive)
	mg/l										**mg-equiv/l**	**mg/l**	**mgO/l**		**mgO/l**	**mgSiO_2/l**	**mg/l**
4k	22.4	40.3	517	<0.01	<0.05	10.4	1.9	139	39.7	0.04	10.2	771	4.52	7.16	6.9	7.24	6.93
5k	6.6	49	474	<0.0.1	<0.05	6.8	4.6	128	37.1	0.461	9.44	707	3.41	7.5	17.7	**10.88**	5.61
6k	5.2	22.8	367	<0.01	<0.05	5.2	1.6	89.6	24.9	0.165	6.52	517	1.31	7.47	12.7	8.5	<5.0
8k	5.9	1.5	427	<0.01	<0.05	22.5	2.7	93.8	27	0.218	6.9	581	3.41	7.38	29.1	**19.79**	<5.0
9k	5.8	20.1	563	<0.01	<0.05	26.9	3.5	98.8	34.9	0.447	7.8	754	2.1	7.61	19	9.97	<5.0
10k	5.1	17.8	344	<0.01	<0.05	4.6	3.1	92.4	24.7	0.495	6.64	493	1.57	7.43	8	9.55	<5.0
12k	20.2	21.1	420	1.34	20.6	16.3	2	103	35	<0.01	8.02	640	0.79	7.42	36	**19.72**	<5.0
14k	105	98.4	298	0.305	7.39	53.6	2.6	120	29	<0.01	8.37	714	4.46	7.18	38.2	9.13	26.9
15k	14.7	11.3	574	<0.01	9.16	17.3	1.7	132	43.7	0.036	10.2	804	6.3	7.3	33.5	**16.64**	<5.0
16k	69.2	6.2	455	<0.01	<0.05	45.2	5.8	106	27.6	3.54	7.56	718	**7.61**	7.07	96	**13.13**	16.39
19k	28.9	5.6	416	<0.01	0.239	14.9	1.2	106	30.5	<0.01	7.8	603	2.62	7.2	26.4	12.5	<5.0
20k	9.4	1.9	789	<0.01	<0.05	13.5	2.7	213	32.5	0.152	13.3	1062	**9.18**	6.87	30.8	**24.49**	45.4
6k (groundwater)	77.5	51.4	788	<0.01	<0.05	31	5.5	207	62.5	0.385	15.5	1223	2.1	6.84	22.3	**18.53**	17.6
7k (groundwater)	9.6	11.9	459	<0.01	0.248	18.5	2.9	101	32	0.084	7.67	635	2.1	7.24	18	**13.48**	<5.0
8k (groundwater)	3.6	14	215	0.066	39.1	3.7	1.6	71.2	17.7	0.202	5.01	366	1.31	7.5	11.6	5.55	8.36
Pond near bore 21k	57.5	<1.0	283	<0.01	<0.05	32.8	3.7	71.1	17.3	<0.01	4.97	465	**9.84**	7.04	36.5	3.31	<5.0
Pond near bore 24k	36.9	1.3	466	<0.01	<0.05	27.6	9.2	104	28.3	**4.08**	7.52	677	**16.3**	7.09	24.4	**12.15**	<5.0
Rivulet near bore 13k	33.3	3	463	<0.01	0.319	28	10.7	111	27.8	**12.9**	7.83	690	**9.18**	7.2	77	**23.23**	13.9
MAC	**350**	**450**			**50**	**200**				**2**			**6.5**	**6-9**		**10**	

Table 4.1.1.21. Concentration of phosphorus and nitrogen compounds in water bodies of the Stabatiškė site, mg/l

Place, sample	**Date**	**N/ NO_2^-**	**N/ NO_3^-**	**N/ NH_4^+**	**N_{min},**	**N_{org},**	**N_b,**	**P_b,**	**P_{min},**	**P_{org},**
Point 1	**7 April 2006**	**0.156**	0.121	**2.400**	2.677	0.012	**2.689**	0.028	0.000	0.028
Point 2		**0.153**	0.020	**1.174**	1.347	0.244	1.591	0.044	0.011	0.033
Point 3		0.061	0.272	0.060	0.393	0.743	1.136	**0.122**	0.006	0.117
Point 1	12 April 2006	0.004	0.182	**0.843**	1.029	0.183	1.212	0.017	0.000	0.017
Point 2		**0.034**	0.122	0.362	0.518	0.558	1.076	**0.111**	0.006	0.106
Point 3		0.000	0.674	0.061	0.735	0.022	0.758	**0.333**	0.000	0.333
Bore 4		**0.400**	0.129	0.196	0.725	0.184	0.909	0.061	0.014	0.047
Bore 4p		0.003	0.095	0.304	0.402	0.825	1.227	**0.174**	0.121	0.053
Bore 6		0.003	0.997	0.080	1.080	0.056	1.136	0.094	0.014	0.081
Swamp		0.029	0.198	0.000	0.227	1.045	1.273	**0.256**	0.011	0.244
Snow		0.004	0.207	0.156	0.367	0.997	1.364	0.044	0.008	0.036

Drainage options

The highest western hill (160.0 m a.s.l.) and the nearby middle hill (157.4 m) are the best suited area for the construction of the repository in the Stabatiškė site (A. Rimidis, 2005). The surrounding areas are too wet; there are open water bodies formed as a result of works performed during the construction of the power plant; therefore, drainage should be performed in the construction zone, in the area of approximately 30-35 ha. Hills should have to be lowered by removing the top layer. The analysed maximum possible grounding is respectively up to 154.0 m and 153.5 m of absolute height. It would be new height of the surface of the earth, just about 0.5-0.8 m higher than local descents used by water for flowing to lake Drūkšiai along ditches and washes. In such case the total area of the surface of the hills would become approximately 12 ha. The removal up to higher levels would result in the decrease of the effective area.

The heights of the lowest points (145.7-153.0 m) of the Stabatiškė site allow to plan drainage measures for the protection of the foundation of the radioactive waste repository from the dam of groundwater, in respect to the level of lake Drūkšiai (141.6 m). It is well worth of constructing a multilayer drainage from natural filtering substances, i.e. coarse-grained sand, gravel and broken granite, for the protection of the foundation of the radioactive waste repository from the dam of groundwater. The principal drainage layer of broken granite would be constructed on the layers of coarse-grained sand and graven by placing the bigness of fractions according to the direction of water flow. The thickness of the broken granite layer would be 30 to 60 cm, with the 1-2% inclination towards drainage collectors. It will be covered with a horizontal layer of gravel and then with a horizontal layer of coarse-grained sand. The thickness of layers is 20 cm each.

The condition of the wetland located in the north-eastern corner may be improved by deepening the wetland and by making it into a nice pond. It would perform the function of a compensating basin and would accommodate surplus water caused by melting and heavy precipitation.

COMPARISON OF HYDROLOGICAL AND HYDROGEOLOGICAL CONDITIONS OF THE SITES

Similarities of hydrological and hydrogeological conditions of the sites are as follows:
1. All sites are located near large lakes in the basin of lake Drūkšiai;
2. The hydrological regime of all sites has been reorganised.
Principal differences of hydrological and hydrogeological conditions of the sites are as

follows:

1. Galilaukė hill is the most vivid, and its has the best conditions for the run-off of surface water;

2. The hydrogeological situation of the Apvardai site is more complicated than that of the Galilaukė site, while the level of water is higher;

3. Even though the hydrogeological situation of the Stabatiškė site is more complicated (the middle aquifer occurs closer to the surface of the earth, the upper low permeable span is thinner) than that of the Galilaukė site, there is no danger of flooding in central sections of hills up to the altitude of 154.0 m and 153.5 m.

4.1.2. Meteorological and climatologic data (ambient air)

General information on meteorological and climatologic data sources of the sites

The investigated burial grounds are located in the Aukštaičiai sub-area, the climatic district of the Southeast highlands. This district is characterized by intensification of turbulent exchange and thermal convection in highly traversed area and formation of strong thermal inversions in winter. The nearest station from the planned burial ground is Dūkštas meteorological station at a distance of 12 km from Apvardai, 18 km from Galilaukė and 16 km from Stabatiškė sites, therefore the characteristic meteorological information for this district is provided according to the data presented by this station.

In the area of the Ignalina NPP Dūkštas meteorological station is the unique systemic station for the monitoring of climate elements. The station operates from 01 January 1972 and belongs to the net of Dūkštas meteorological stations of Lithuanian Meteorological Service. These stations provide measurements according to the standards of World Meteorological Organization (WMO); therefore the data of Dūkštas MS can be compared with the data of other meteorological stations performing measurements according to the same standards.

The parameters currently observed in the main Dūkštas meteorological station are the following: air temperature, atmospheric pressure, air humidity, atmospheric phenomena, wind direction and wind speed, natural atmospheric and catastrophic meteorological phenomena, hourly air temperature recorded by thermograph, hourly air temperature recorded by hygrograph, rainfall intensity recorded by pluviograph, soil humidity, soil surface temperature, soil temperature during a vegetation period at a depth of 5, 10, 15 and 20 cm, soil temperature at a depth of 0.8, 1.2, 2.4, 3.2 m, sunshine duration recorded by heliograph, daily snow coat thickness, snow photo in the forest, phenomena of freezing rain, hoarfrost, glazed frost, and phenological phases of trees and bushes.

The other nearest sources of climate data is Utena meteorological station (about 56 km from the objects), Švenčionys (around 50 km) and Rokiškis (around 78 km) ordinary climate stations (according to the nomenclature of the Lithuanian Hydro meteorological Service). In case meteorological data must be reconstructed, partially may be referred to the meteorological data of former Duseta, Zarasai, Ignalina, Švenčionys meteorological stations and Moliakalnis (near Dūkštas), Naujasis Daugėliškis (near Ignalina) and Vyšniauka (near Zarasai) meteorological posts. Some facultative data about the state of climate elements of the region can provide air monitoring posts of Ignalina NPP operating for 10 years. Their monitoring programs vary. Meteorological posts of nuclear power station measurements performs according to their individual program, therefore in order to compare data of one station with the data of other station additional statistical data analysis must be provided.

Meteorological conditions of a terrain

The data of Dūkštai meteorological station are provided in Tables 4.1.2.1 – 4.1.2.3 and Figures 4.1.2.1 and 4.1.2.2. West and southwest wind predominate in the sites. One of the possible burial grounds is at Galilaukė hill, the long axis of which is oriented towards the east – west direction. The other possible burial places in the terrain of Lake Apvardai are provided in the hills, extended in the north-south direction. The different exposition of hill slopes can influence the formation of snow coat during the cold season. Different amount of sun radiation falling on the slopes can determine uneven intensity of snow coat melting.

The average steady (lasting shorter than one month with the brakes not longer than three days) snow cover is formed on 15 December. The biggest thickness of snow cover is 25 cm. A constant snow cover disappears on 25 March.

Table 4.1.2.1 Perennial frequency of wind direction (%) at Dūkštas MS (Lithuanian ..., 1996)

Wind direction	Frequency of wind direction, %		
	January	July	Annual
N	5	10	8
NE	6	8	7
E	14	8	12
SE	15	8	13
SP	12	7	11
SW	23	17	19
W	16	24	18
NW	9	18	12
Calm	3	9	6

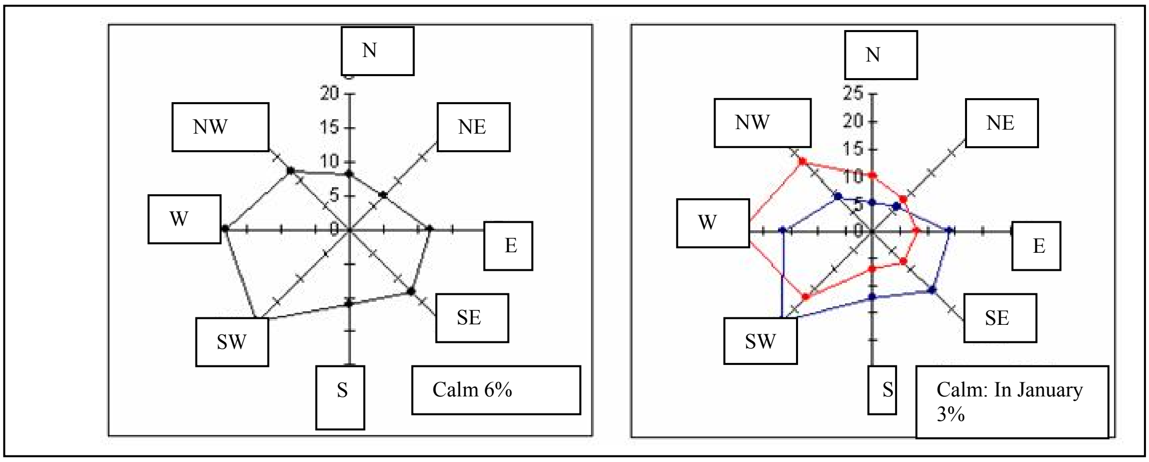


Fig. 4.1.2.1 Wind roses of perennial period at Dūkštas MS: on January – on the right - blue color, July (on the right - red color), per year (on the left)

Table 4.1.2.2 Perennial average wind speed at Dūkštas MS (Lietuvos ..., 1996)

Wind direction	Wind speed, m/s		
	January	July	Annually
N	2.8	2.5	2.8
NE	3.4	2.7	2.8
E	3.6	2.6	2.9
SE	4	2.6	3.2
S	3.8	2.9	3.3
SW	4.1	3.1	3.6
W	4.2	2.8	3.6
NW	3.4	2.7	3.1

Table 4.1.2.3 Average perennial amount of rainfall (mm) and average maximum and minimum perennial air temperature for a day (°C) at Dūkštas MS (Lietuvos ..., 1991, 1992)

Indicator	Months												Per year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Average temperature	-6.8	-5.6	-1.8	5.2	12.1	15.5	16.8	15.9	11.2	6.2	0.9	-3.8	5.5

Maximum temperature	-4.0	-3.0	1.9	9.8	17.3	20.5	21.6	20.9	15.6	9.5	3.0	-2.5	9.2
Minimum temperature	-9.0	-8.3	-4.9	1.2	6.8	10.2	11.7	11.0	7.5	3.3	-0.9	-5.9	1.9
Rainfall amount	31	25	29	43	56	75	81	74	68	51	41	40	614

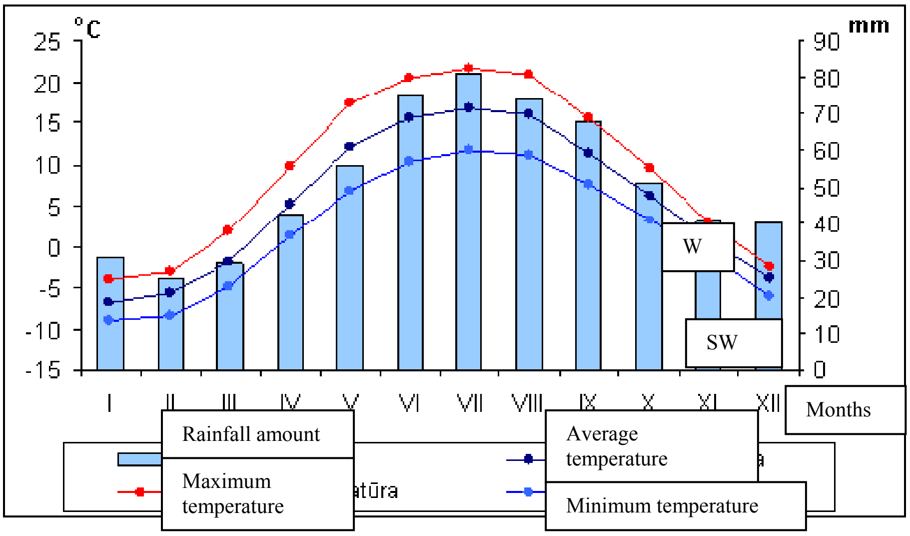


Fig. 4.1.2.2 Average perennial amount of rainfall (mm) and average perennial maximum, average and minimum air temperature for a day (°C) at Dūkštas MS

Tendencies of climate changes

According to the results of the models developed in different world countries adapted for Lithuania *(Bukantis, 2001*), the air temperature of the XXIst Century Lithuania should rise. It is assumed that the climate will change more quickly at the second part of this century. It is forecasted that the air temperature of cold period will especially rise (on December/March). Besides, the total amount of rainfall and frequency of rainfall anomalies will rise (during the cold period in particular). This demonstrates that the contrast between the year seasons abates and the intermediate seasons get longer. On the other hand, it is clarified that the cases of long-term hard frosts decreased, whereas long-term fevers more often repeat. Tendencies of these anomalies frequency are in tone with other indicators of climate extremalities. The investigations of climate tendencies and modeling show, that the tendencies of Lithuanian marine climate will become more distinct.

The intensive supervision of radioactive waste burial will be executed for 100 years; therefore it is important to provide for the tendencies of climate change in the district. The best way how to achieve this is the carbon dioxide emission scenario of IPCC (Intergovernmental Panel on Climate Change) and global atmosphere circulation models of GCM (General circulation model). According to them during the nearest one hundred years the air temperature in Europe should rise from 0.1 to 0.4 °C per decade. The biggest temperature rise is provided for in the South Europe and north part of Europe, to which belong the Lithuanian territory too. Especially quickly should rise the air temperature of cold period – from 0.15 to 0.6 °C per decade. The air temperature of warm period would raise not so quickly – 0.08-0.3 °C per decade *(Climate ..., 2001)*. Increase of annual rainfall amount is provided for in the North European part. It is supposed that the amount of rainfall would raise 1-2 % per decade. The amount of cold period rainfall should increase – 1-4 % per decade (Clima*te ..., 2001).*

Summary of meteorological and climatic data

According to the long-lasting object safety and operation, the differences between the zones of climate parameters (regional), climate anomalies and climate change tendencies do not have impact on a suitable selection of burial ground.

According to the location and characteristics of Galilaukė and Apvardai sites it may be stated that the most contrasting exposition slopes - north and south – prevail in the sites, what can determine significant differences between the elementary run-off formation conditions, soil temperature regime and other microclimatic differences in separate parts of burial ground.

4.1.3. Soils

Soddy-podzolic soils are repeated in the hilly highland of East Lithuania; surface outwashes are badly decayed in the slopes of the hills. Soddy-podzolic sand soils, sandy-loam soils and loam soils dominate in this region.

APVARDAI SITE

The preliminary investigated soil area at Apvardai site is around 275 ha, the territory of the hills and adjacent area investigated in more detail is around 51 ha. The mechanical composition of a surface is not smooth, however not very mixed too. Sub-soils of more light mechanical composition prevail in the Galilaukė soil. Peat is formed in the depressions, which can be found practically in the entire territory.

A very similar mechanical composition is noticeable in the territories, which were investigated in more details: medium loan soils and peat in the depressions prevail.

In general, the genetic soil diversity of a site is not big (Fig. 4.1.3.1). Podzolic Luvisols, Luvisols and saturated Albeluvisols prevail deep and shallow peaty soils of low-moor dominate in the depressions (Histosols). Peaty soils available in the central part were drained and in that area pasture lands were established. A rather big part covers rip soils – simple carbonate Regosols and medium eroded carbonate Luvisols due to agraric activity and mechanical land excavation and leveling before equipping the greenhouse complex. When construction of greenhouses was started in the southeastern part of this site, a layer of fertile soil was excavated and took out from around the area of 25 ha and here is found deeply excavated simple carbonate Regosols.

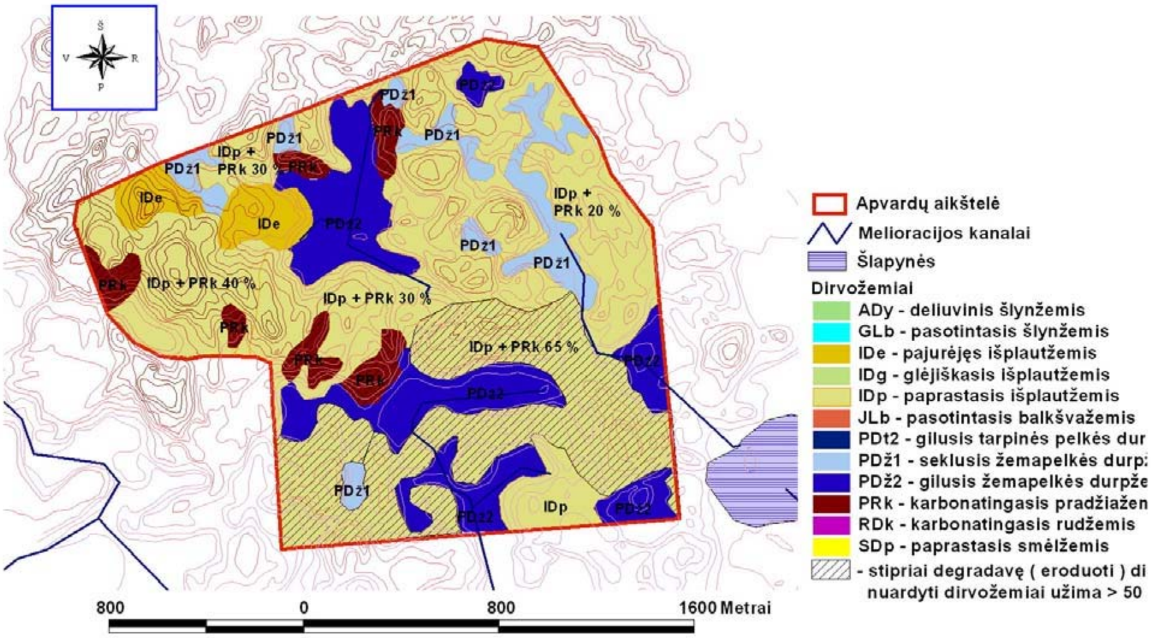


Fig. 4.1.3.1 Soils of Apvardai site

Ordinary podzolic Luvisols, simple Luvisols, saturated Albeluvisols investigated in more detail compose about 52% of the territory. About 45 % compose ordinary carbonate Regosols, moderately eroded Luvisols and deeply ripped ordinary carbonate Regosols. Deep low-moor Histosols, which are also drained, covers about 2%.

GALILAUKĖ SITE

The preliminary investigation of soils at Galilaukė site is performed in the area of around 76 ha and the hill territory and its nearest environment was investigated in more details in the area of 76 ha.

Mechanical composition of this soil surface is heavier than those of Apvardai site. Moderate and hard loam (light, moderate and heavy loam) or even clay is found frequently. In the north part the mechanical composition is lighter: here sandy loam and even several patches of sand can be found, however it composes only 1% of the total area. At the foot of the slope and in the depressions between the hills a rather big area occupies peat: in the northeast part near Lake Drūkšiai, and in the south and central parts (crop grasslands and pastures were established in these areas after the land-improvement works).

The covering of the soil in this territory is not very diverse, however rather divided (Fig. 4.1.3.2). Simple podzolic Luvisols, simple Luvisols, and saturated Albeluvisols here dominate. Deep low-moor Histosols are found in the north-east part near Lake Drūkšiai and central part, in the south part – deep medium-moor Histosols, in the last two areas peat is drained and farming lands are established, there intensive land-improvement works are going on. Rip eroded soils – carbonate Regosols and moderately eroded carbonate Luvisols covers not a very small part (due to intense agricultural and earlier performed equalization works of the territory).

In the southwest angle shallow carbonate Cambisols, in the southeast part of the territory (near the Drukšė river) - ordinary humus Fluvisols and ordinary peat Fluvisols can be found, however they cover no more than1-2% of the total area.

In the north east part ordinary Arenosols and ordinary podzolic Arenosols are formed on the sand (SDc-p).

Mechanical composition and soils are similar in the investigated territory: ordinary podzolic Luvisols, ordinary Luvisols, and saturated Albeluvisols are formed on the heavier hard loam or clay soil and they cover almost 70% of the territory. Rip soils – ordinary carbonate Regosols and averagely eroded carbonate Luvisols - cover more than 15%. Deep low-moor Histosols formed on the peat is found in the east part, they comprise about 9%. Saturated deluvic Cambisols, which were formed from the eroded products due to agricultural activity in the slope of the hills, are also found in the said territory. Deluvic Fluvisols are dislocated in a narrow several meter long zone in the lower part of the slopes of the hills. Typical saturated Gleysols formed in more damp places are found too. However, both these soils occupy only several percentage of the total area.

Mechanical composition of a surface of Galilaukė site is a little bit heavier than the Apvardai site, it is less sensible for the anthropogenic influence.

Mechanical composition and soils in the investigated territory are similar: ordinary podzolic Luvisols, ordinary Luvisols, and saturated Albeluvisols formed on the heavier hard loam and clay dominate are found; they occupy almost 70% of the territory. The rip soils – ordinary carbonate Regosols and moderately eroded carbonate Regosols comprise more than 15%. Deep low-moor Histosols formed on the peat, are found in the east part, they comprise about 9 %. In the said territory deluvic saturated Cambisols are formed from the eroded products, which were formed during the agriculture activity on the slopes of the hills. Deluvic Fluvisols are dislocated in a narrow zone of several meter length in the lower part of the slopes of the hills. Typical satiated Gleysols are also found in more damp places. However, both these soils occupy only several percentage of the total area.

Mechanical composition of a surface of Galilaukė site is a little bit heavier than the Apvardai site; it is less. Sensible for the anthropogenic influence.

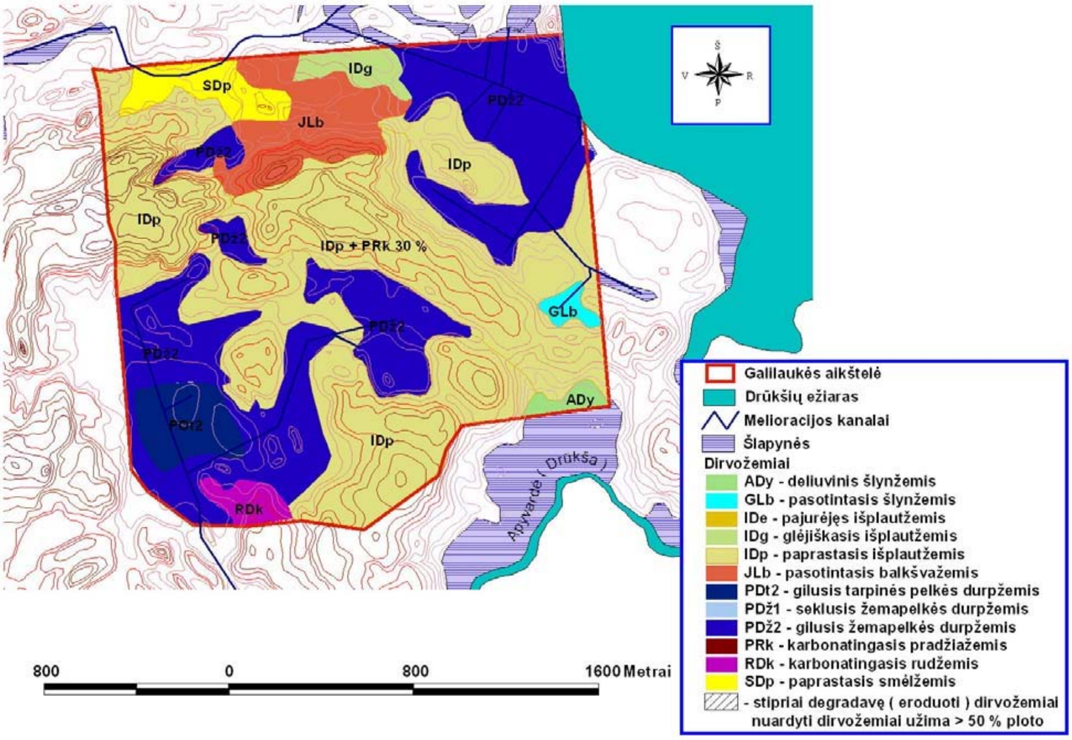


Fig. 4.1.3.2 Soils of Galilaukė site

STABATIŠKĖ SITE

Soddy podzolic sand, sandy loam and loam soils prevail in Stabatiškė site like in the entire East Lithuanian Highland.

Soddy-podzolic, moderately podzolic ($J^V{}_2$) and soddy-podzolic gleic ($JP^V{}_1$) soils dominate in the Stabatiškiai site. According to the mechanical composition of soils a light plastic clay and fine sand dominate in the site, less light plastics loam is found in the site, and peat is found in the lower places. Due to the earlier agriculture, the slopes of the hills are eroded, ripped.

4.1.4. Relief

Geomorphologic and topographic conditions of Ignalina NPP are very diverse. Data about the characteristics of this relief may be found in the scientific publications (*Basalykas, 1965; Kudaba, 1983; Česnulevičius, 1999*). The relief of the region was already investigated in the earlier studies (*Nuclear ..., 1997)*, was discussed in the materials on burial ground substantiation and selection of the sites (*Identification ..., 2004*).

Hilly, abounding in lakes, cut with ravines, moraine loam and fluvioglaciel sandy marshy hog backed plain prevail in the north east part of the region, where the investigated sites are located. A land of rather narrow but sheer slopes moraine backs and crest hill chains are characteristic to the northeast micro district of the region. There are plenty of small, but deep low-moor bogs in the inter-crest hollows.

APVARDAI SITE

Apvardai site is surrounded by various sized moraine hills. From east and southeast (from Žibakiai) the site is surrounded by small and averagely massive hills with small dampen hollows. Small hills are of 10-15 m height (according to the adjacent marshes and the deepest hollows), rather sheer (especially in the east part). Slopes are usually short (up to 150 m). A big variety of expositions (more slope expositions of east-west), this zone of the hills as if delimits the Apvardai site from a rather wide (1-3 km) zone of bogs of Kukutėnai – Gaidė – Čepukai.

More massive and shallow formations, and more massive hollows prevail in the north and north east part of the site The relative height of the hills reaches 16-20 m, the length of the slopes – 200-250 m. The most massive and highest (the relative height of 20-26 m) relief formations are in the perimeter of northwest site, in Guriai, Tripuckai, Pušynas terrains.

From the west, the site is surrounded by a zone of moderate hills of shallow slope and waves (12-15 m height) delimiting the described territory from a range of small marshes extending in the north-south direction between Magūnai and Bieniūnai.

The surface of the south part of the territory was leveled, when a construction site for green-houses group of NPP was prepared. The leveled area covers not less than 25 Ha, its surroundings were reformed too (the slopes of the neighboring hills were leveled, self-flowing hollows were formed). Until leveling this part of the site wide, swamped hollows and shallow sloped waves of 4-9 m height dominated in this site.

The main surface element (from the point of possible establishment of burial ground) in the Apvardai site is a hill of a complicated form (with several low crowns), which in the north joins the hill of Kumpiai forest. The main hill of the burial ground covers around 24 ha (with the hill of Kumpiai forest – 37 ha). In the west it joins to significantly massive and higher hill near Tripuckai (terrains of Supakalnis and Klevas Mountain): the relative height of the latter is 22-26 m. In this case, the total area of the complex is 98 ha. This complex is noted for its complicated surface structure (about 15 peaks), big surface elevations inside the outline (up to 26 m). Therefore, only the main investigated hill of the burial ground between channel K-6 in the east and the first deep depression between the hills in the west is further described. A hill (according to the local inhabitants named Mikštas hill) in the east-west direction extended for about 600 m, its width is around 400 m. Some characteristics are provided in

Table 4.1.4.1. Due to a complicated structure only the approximate total areas of various elements of slope expositions are denoted. The north, north-east and north-west slope expositions cover 24%, east, southeast expositions – 11%, southwest – 11%, south – 50% of the area. There are not many flat surfaces there. The crowns of the hills are in the absolute height of 161-165 m.

Table 4.1.4.1 Main morphometric characteristics of the hill at Apvardai site

Indicator	**Northern slopes**	**Southern slopes**	**West slopes**	**Eastern slopes**
Relative height of a slope, m	8 - 10	12 - 16	10 - 14	9 - 13
Length of a slope, m	60 - 90	140 - 180	80 - 150	100 - 180
Steepness	6 - 9	6 - 9	7 - 12	4 - 6
Slope profile	Convex dominates	Complicated	Convex dominates s	Convex

GALILAUKĖ SITE

The main surface elements determining the dissection and structure of an elementary pool in Galilaukė site are the following:

- Vosyliškiai back/crest (around 2 km length in the east and west direction, 0.2-0.5 km width, the relative height of the hills – up to 1-22 m, absolute height – 153-169 m);
- Crest-like Galilaukė hill (1.2 km in the direction of north southeast, 0.2-0.4 km width, relative height – 6-21 m, the higher part is in the north west part; absolute height – 152-164 m, in the south end – spurs in the northeast and southeast direction, relative height of 10-15 m);
- Švikščioniai crest (around 1.8 km length in the north east-southwest direction near the Drūkša River, 0.3-0.6 km width, relative height from the side of Drūkša – 18-20 m, absolute height – 160-164 m; a marsh of 50-250m width separates from Drūkša).

Various sized hills in the shape of small islands (1-5 ha) and waves, the relative height of which is 6-14 m, are found in a relatively closed trough of the said relief elements. From the west the site is almost closed by Varniškiai crest (the relative height of the hills in the north and south part is 10-22m, in the middle – 4-8 m). In the south part it abuts to the especially expressive deep surface dissection distinguished for a band of high hills of massive and average sheer slopes running near the Drūkša River in the north east-southwest direction. Thus, there are different directions (according to the long axis) and formations of uneven dissection in the interaction forming a relatively closed, the so called Galilaukė basin. The formations of its perimeter are similar to the morphometric.

The hill, where the cellarage of burial ground will be established, runs for 1.2 km in the north west-southeast direction. The width of the hill is 0.4 m (in the northwest part) and 0.2 km (in the southeastern part). Near the north end of the hill in the east-west direction for 2 km runs a narrow (0.2-0.5 km) Vosyliškiai crest with several crowns, the absolute height of which is 153-169 m. Small surface forms and more variegated lithology dominate here. The area of Galilaukė hill is around 38 ha. Some of its characteristics are provided in Table 4.1.4.2.

Table 4.1.4.2 Morphometric characteristics of Galilaukė hill

Indicator	Northeastern slope	Southwestern slopes	Northwestern slopes	South-southeastern slope
Relative width of the slope zone, ha (%)	3 (8)	13 (34)	17 (45)	5 (13)
Relative height of the slope zone, m	16-21	8-15	6-8	11-16
Length of a slope, m	100-250	100-200	~150	150-300
Steepness	7-12	<6	3-6	4-7
Slope profile	Convex	Smooth surface, in places – conceive	Conceive	Convex

STABATIŠKĖ SITE

The relief of the site territory is especially hilly. There is several low hills of an oblong form, separated by depressions, part of which is swamped (*Račkauskas V., ..., 2005*). The hills of Stabatiškė site are perfectly visible in a photo made in 1952 (Fig. 4.1.4.1). Earlier the hills were tillable, and in lower places there were pastures and forests. The relative height of the hills above its surrounding depressions comprises 6-9 m. There remain 3-4 homesteads. The maximum absolute height of the hills where it is provided to establish the burial ground is 160.09 m. The lowest absolute height of the entire territory is 146.84 m in the north-eastern angle, in the marsh. In many places during the last 30 years the lowest relief forms changed due to the waterlogged territories, several embankments or excavated ground during the construction works.

The maximum lean angle of a hill slope - 7^{o}, dominating - 5^{o} (*Taminskas J., 2005*). According to the topographical map M1:2000 in some topical segments of investigated hill slopes, especially where beam approaches to the hills, the calculated lean angle achieves 14-20^{o}. These ravines are the old ravines covered by forest, which are found near the northern and eastern edge of the central hill.

Fig 4.1.4.1. The aereo-photo of Stabatiškė site made in 1952

<u>COMPARISON BETWEEN PECULIARITIES OF THE SITES' RELIEF</u>

1. The slopes of the hills of all investigated sites are not sheer and are not hazardous to the buildings.

2. The incline of a surface in all the sites towards the water bodies makes the conditions for the rainfall water to escape to the surface water bodies. The water escape conditions at Galilaukė site are the best, since the surface incline is the biggest and water bodies (Lake Drūkšiai or the Drūkša River) are the nearest. The water escape conditions at Stabatiškė site are the poorest.

3. The dominant relief forms at the Galilaukė site (differently from Apvardai site) form a relatively closed local basin, advantageous for monitoring.

4. A uniform hill dominates in Galilaukė, on which cellarage of burial ground would be situated. The main hill of Apvardai site is of a more complicated structure and with a clear micro relief. In case of Stabatiškė there is no uniform hill of a sufficient area, therefore cellarage would be situated on two hills. Burial ground in Apvardai or Stabatiškė sites would be of a more complicated configuration and construction accordingly.

4.1.5. The underground resources

Further to south of the range geologic structure and peculiarities of Lake Drūkšiai are comprehensively described on the basis of all data of earlier investigations available in the State Geological Information System. Apvardai, Galilaukė and Stabatiškė sites are described using geologic cartography corpus material and data of special investigations. .

Structure peculiarities of the underground resources

Geomorphologic conditions of the region

Station/range further to the south of Lake Drūkšiai is in the distal part of the Baltic highlands in the band of edge formations formed by retreating glacier of Nemunas age, and in Gaidės glacio depression in the south from Lake Drūkšiai (*Marcinkevičius et all., 1995*). The bigger part of glacio depression occupies moraine hills, surges and fields and arrays in the forms similar to surges. Hills – average and small, with flat-topped crowns, slopes are oblique. The absolute height of 155-165 m prevail, and to the north east from Lake Drūkšiai their height reach 170-172 m. Fluvioglaciel and limnoglaciel hills, drumlins, limno and fluvio kames, eskers and drumlins resembling eskers are characteristic features. Depressions between the hills in the absolute height of 141-145 m usually are swamped. To the south from Ignalina NPP in Gaidės glacio depression Čebarakai massif segregates, the surface of which is coated with a thin coat of zandric sand. Its surface is flat, in places - fine hilly, with thermo-karst cavities. The average and small moraine hills poke in many places from the zandric sand. Fine hills of moraine relief dominate in the surrounding area of the Ignalina NPP.

PreQuaternary rocks

The district of Ignalina nuclear electric station is in the zone of East Europe platform of two massive regional tectonic structures – Mozūrija-Baltarusija anteclises and Latvia saddle (*Suveizdis, 1979*). Therefore its structural tectonic conditions are complicated. According to the surface relief of crystalline basement tectonic structures of lower row (blocks) here are separated by: the North Zarasai step, Anisimovičiai graben, East Drūkšiai uplift (graben) and South Drūkšiai uplift. The step of North Zarasai, Anisimovičiai graben, East Drūkšiai uplift belongs to the Latvian saddle, South Drūkšiai uplift – to Mozūrija-Baltarusija anteclises, and Drūkšiai bend (graben) – to the zone of the said regional structures (*Vaitonis et all, 1976; Marcinkevičius et all, 1995*).

The crystalline basement lies in the depth of 720 m from the earth’s surface. It consists of Proterozoic rocks, which usually include amfibole-biotite gneiss, granite, migmatite, and other. The thickness of the PreQuaternary rocks sediment coating in the region differs from 703 m to 757 m. It comprises the rocks of Vendian complex and Paleozoic rocks. Vendian complex consists of gravelite, varigrained quarz-feldspat-sand, aleurolite and argilite. The Paleozoic geological section is composed of the Lower-Middle Cambrian, Ordovician, the Lower Silurian and the Middle and Upper Devonian rocks (Fig 4.1.5.1. and 4.1.5.2.). The Lower Cambrian is composed of quartz of various roughness, usually fine-grained and very fine-grained quartz, quartz-glauconitic sandstone, aleurorite and clay, the Lower and Middle Cambrian – of fine-grained and very fine-grained quartz-sandstone, Ordovician – of limestone and marl beds, the Lower Silurian – of domerite and dolomite, the Middle Devonian – of gypsum-plaster breccias, domerite, dolomite, also fine and very fine sand, and stone, aleurite and clay beds, the Upper Devonian –of fine and very fine sand and sandstone, aleurite and clay beds. The thickness of Vendian complex is 135-153 m, the total thickness of the Lower and Middle Cambrian rocks is 93-114 m, Ordovician – 144-153m, Silurian – 28-75 m, the thickness of Devonian rocks reaches 250 m (*Marcinkevičius et all, 1995)*.

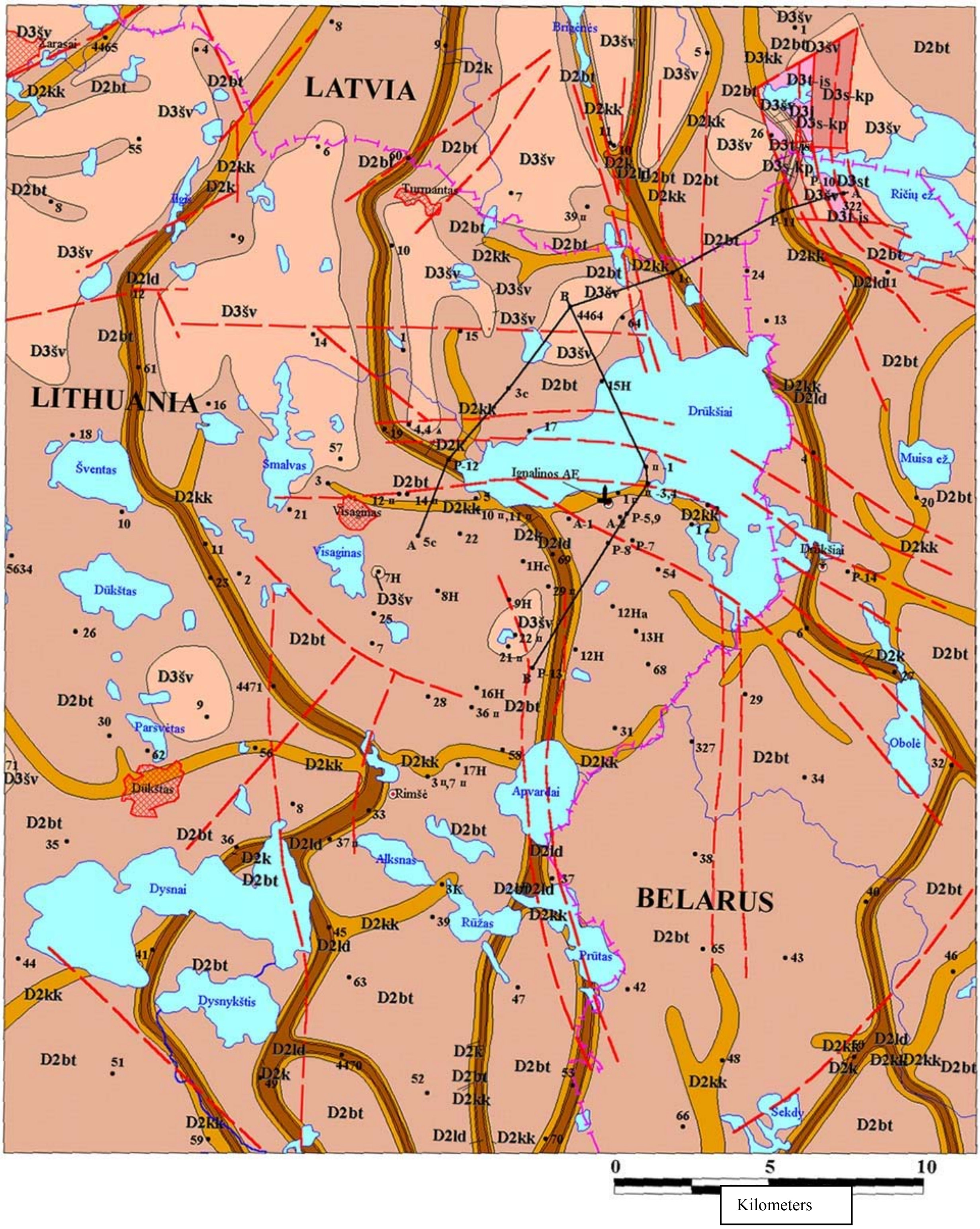


Fig. 4.1.5.1 The PreQuaternary geological map of the Ignalina NPP region ***(Author V. Marcinkevičius, 1995)*****: 1 – Quaternary formations (cross-sections), Fms of the Upper Devonian; 2 - Spokes, 3 –Tatula - Įstra; 4 - Suosa – Kupiškis; 5 - Jara; 6 - Šventoji; Fms of the Middle Devonian: 7 – Butkūnai; 8 – Kukliai; 9 – Kernavė; 10 – Ledai, 11 – Fault, 12 - Line of geological tectonic cross-section; 13- Borehole, 14 – Ignalina NPP.**

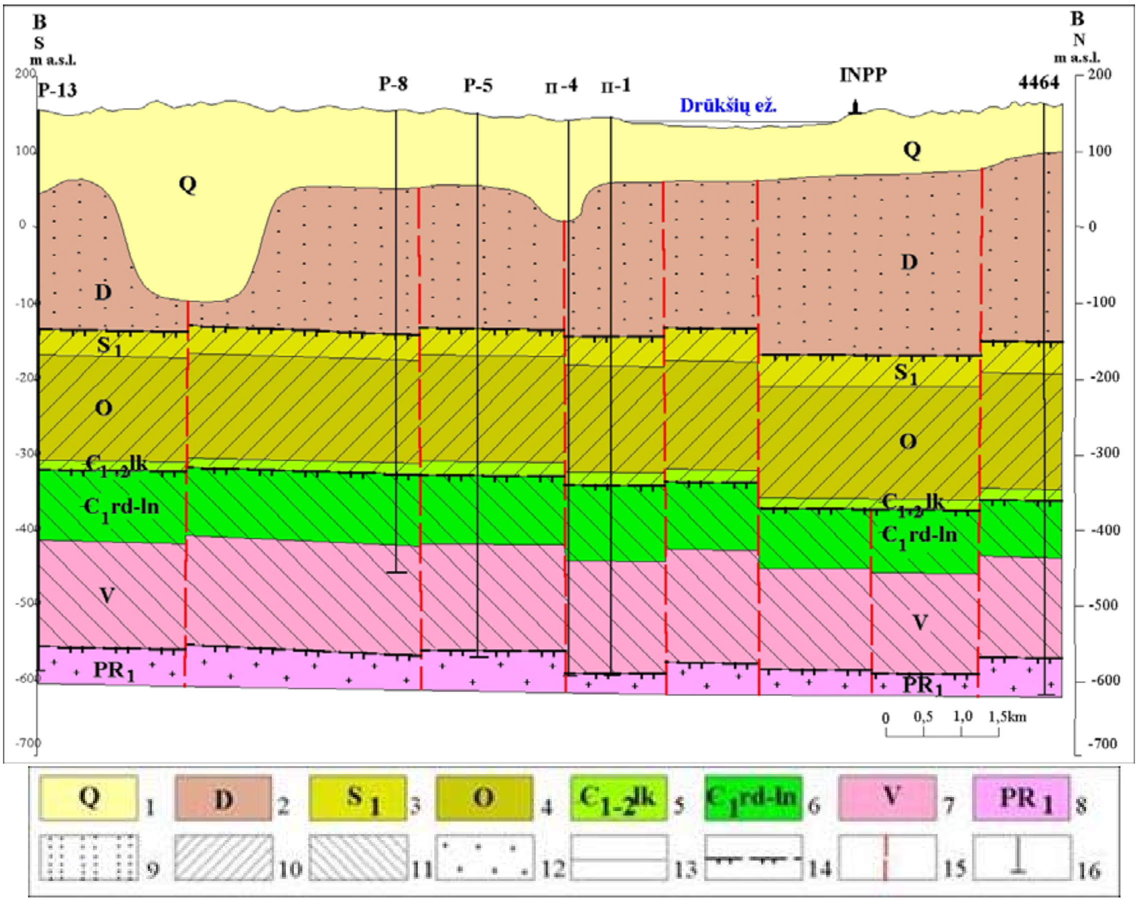


Fig. 4.1.5.2 Geological cross-section of the Ignalina NPP region *(Author V. Marcinkevičius, 1995)*: 1 – Quaternary: moraine, sand, aleurite and clay; 2 – the Middle and Upper Devonian: sand, sandstone, aleurolite, clay, domerite, dolomite, breccias; 3 – The Lower Silurian: domerite, dolomite; 4- Ordovician: limestone, marl; 5 – the Lower Middle Cambrian Aisčiai Group Lakajai Fm: sandstone, the Lower Cambrian Rudamina – Lontova Fm: argillite, aleurolite, sandstone; 7 – Vendian: sandstone, gravelite, aleurolite, argillite; 8 – the Lower Proterozoic: granite, gneiss, amphibolites, mylonite; structural complexes: 9 Hercynian, 10- Caledonian, 11- Baikalian, 12 – Crystalline basement, 13 – Borders between the systems, 14- Borders between the complexes, 15 – Faults.

Quaternary sediments

Quaternary sediments lie on the uneven PostQuaternary surface traversed by paleo incisions (Fig. 4.1.5.3.). Their thickness in the region varies from 62 to 260 m.

The Quaternary thickness is composed of the sediments of the Middle and Upper Pleistocene and Holocene. The sediments of the Middle Pleistocene of Dzūkija, Dainava, Žemaitija, Medininkai glacier and the Upper Pleistocene of Nemunas, Grūda and Baltija stage glacier and their melting water are determined. Glacial sediments (moraine) – moraine loamy and sandy loam lying here in places of up to 60 - 80 m depth without the sandy intermoraine bed (Fig. 4.1.5.4.) prevail in the thickness of Quaternary sediments around Lake Drūkšiai. But most frequently moraine sandy loam and loam in the thickness is stratified with the beds of varigrained sand, aleurites, or clay (Fig. 4.1.5.6). The dominating thickness of intermoraine sediments is from 10-15 to 25-35 m (the thickness of clay beds is from 0.5-1 m to 50-70 m (*Marcinkevičius et all, 1995*).

The regional surface is formed by the last glaciations of the Baltija stage glacier and the sediments deposited directly from melting glacier. Edge glacial formations (moraine) composing the bigger part of the diverse hilly surface of the area prevail. Single hills and their massifs ate composed of varigrained sand: esker, kames and other sediments filling the cracks caused by melting ice. The thickness of the sandy sediments between the troughs of Lakes Drūkšiai and Šventas deposited by glacial melt-water flows in places reaches even 40-50 m. Some peaks of the hills or surface depressions are covered by 2-4 m thick clay beds.

The Holocene sediments (postglacial period) are: alluvial, lacustrine sediments, delluvial (slope sediments) and swamp sediments (peat). They are dispersed in the surface of the entire territory.

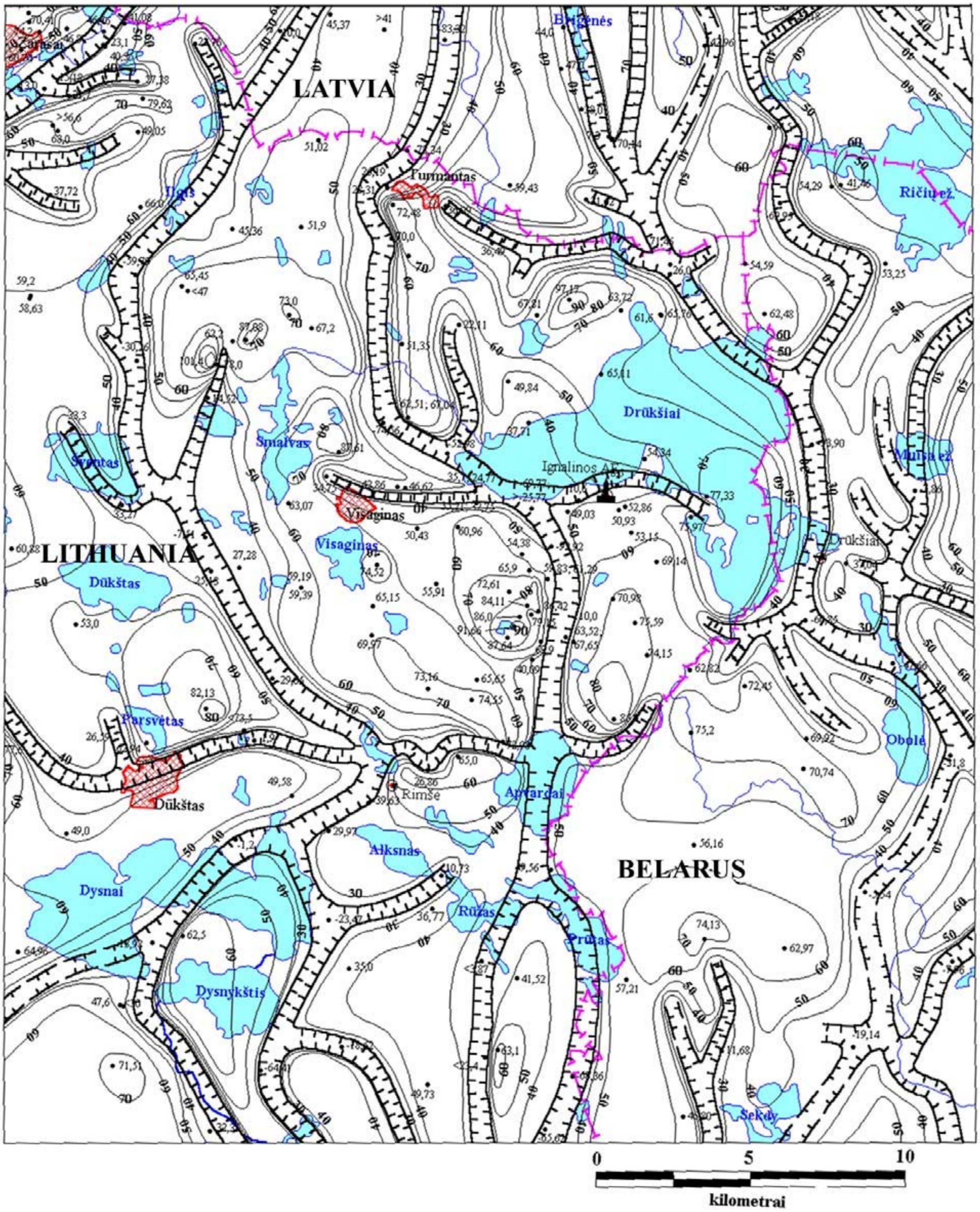


Fig. 4.1.5.3 The scheme of PostQuaternary surface of the Ignalina NPP area (Authors: *R. Kanopienė, V. Marcinkevičius*): 1 – Paleo-incisions, 2 – Isohipses of PostQuaternary surface, m; 3 – Boreholes and the absolute depth of PostQuaternary surface; 4 - Ignalina NPP.

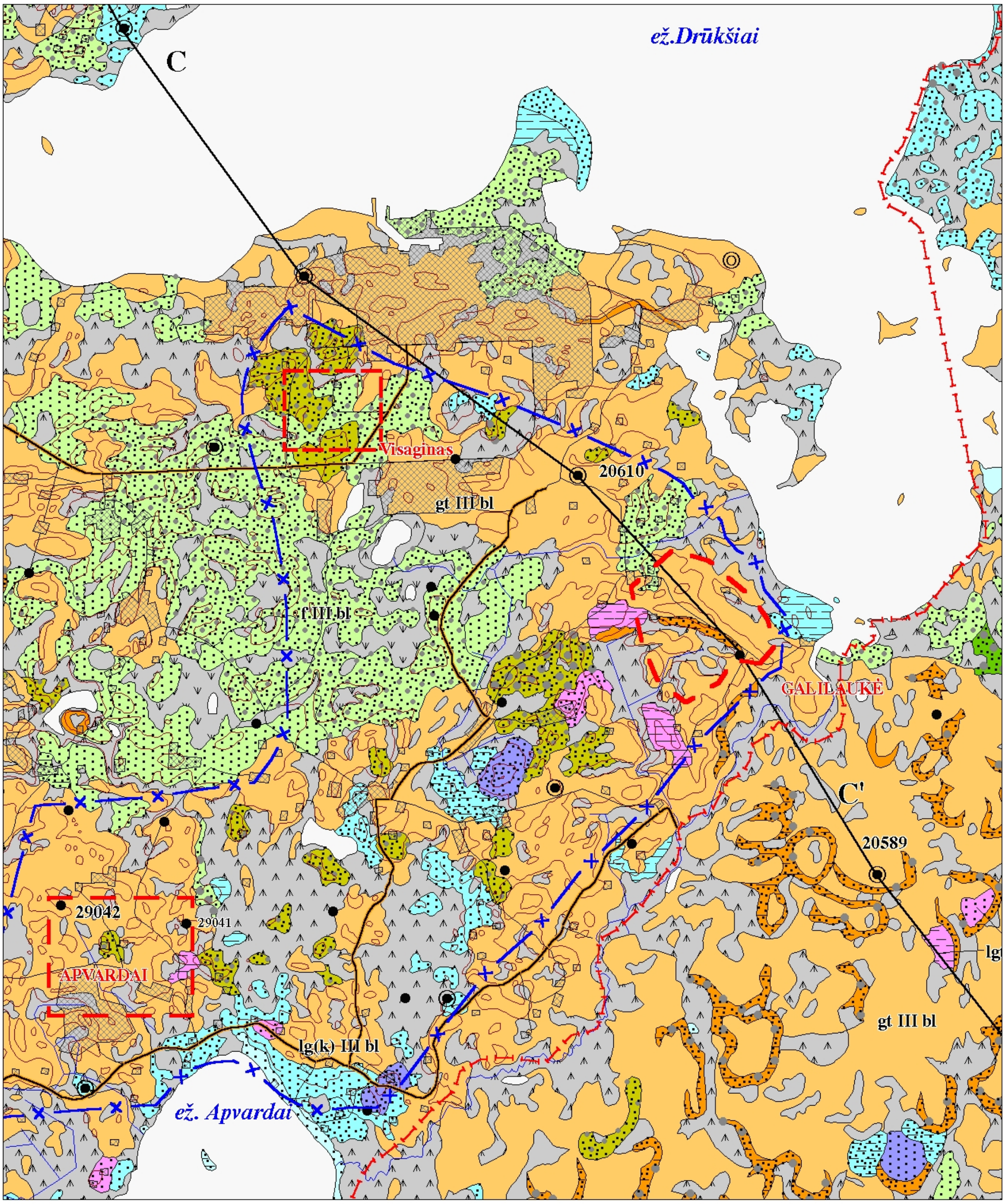
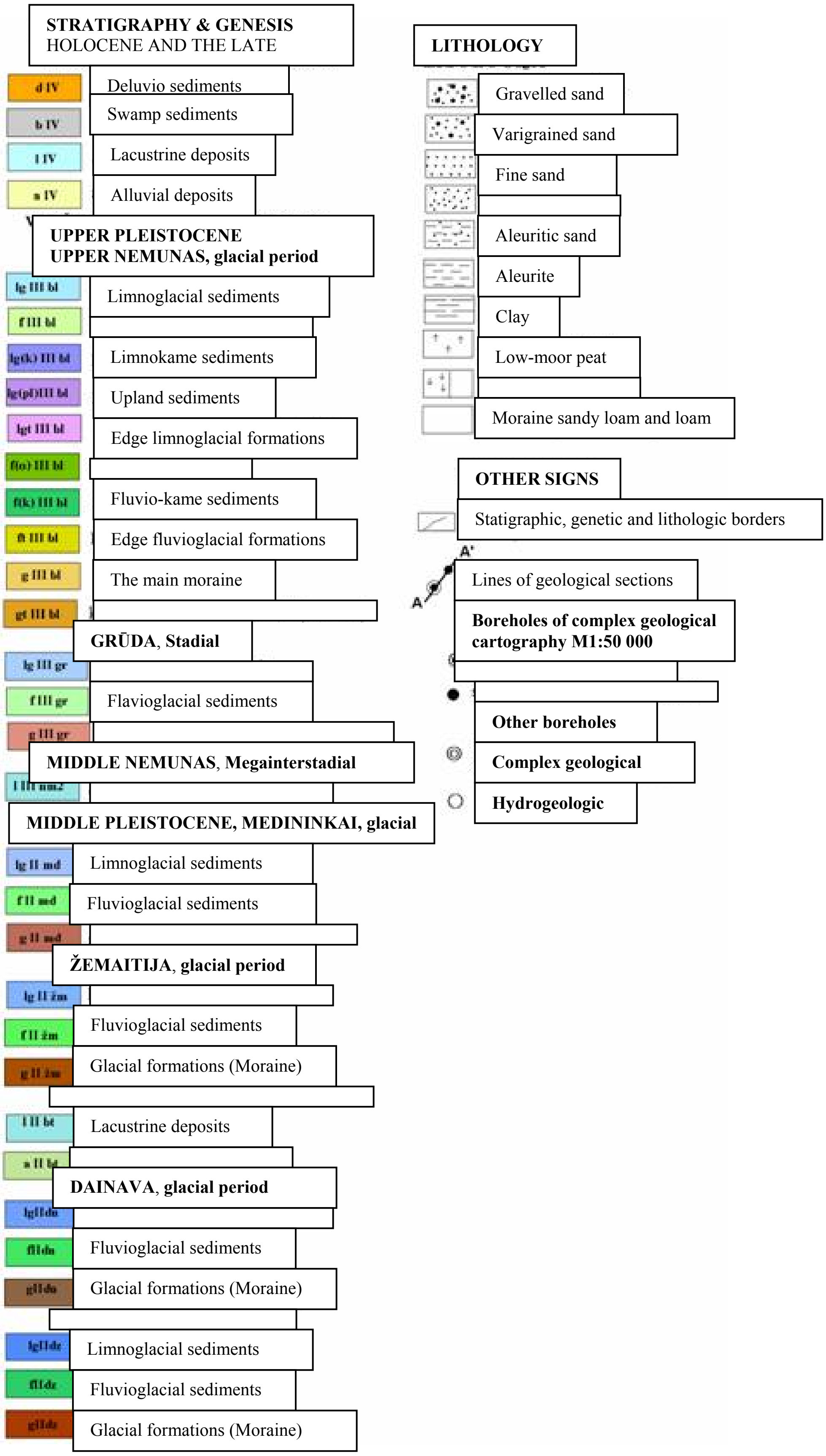


Fig. 4.1.5.4 Quaternary geological map of the Ignalina NPP surrounding area
(Authors: R. Guobytė, V. Račkauskas, V. Marcinkevičius)

Fig. 4.1.5.5 Legend of Quaternary geological map and geological cross-section of the Ignalina NPP surrounding area



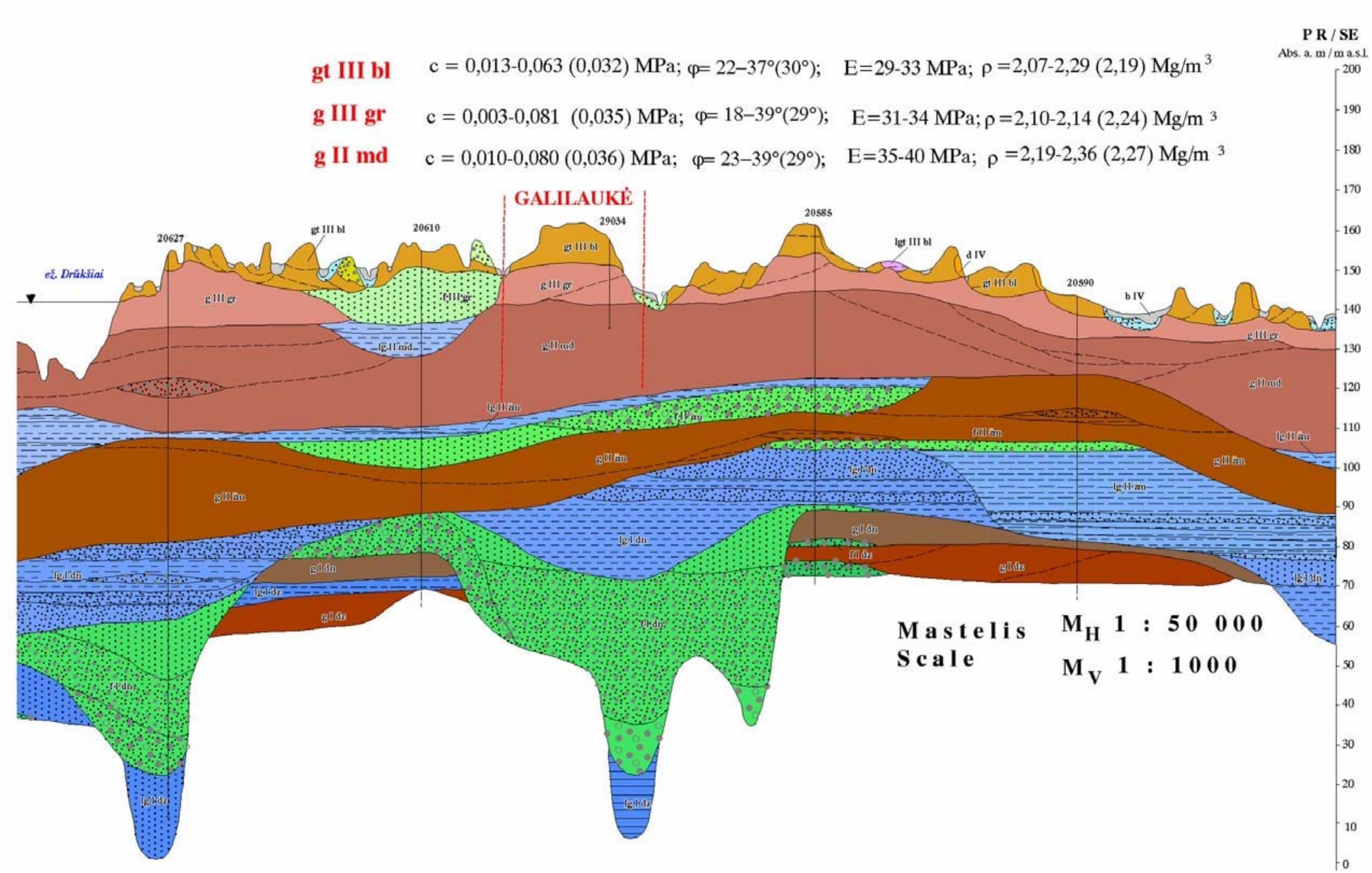


Fig. 4.1.5.6 Geological cross-section C-C of the Ignalina NPP surrounding area (Authors: R. Guobytė, V. Račkauskas, V. Marcinkevičius)

Tectonic, neotectonic activity, seismology

Tectonic faults

There are two types of tectonic faults in the region: a pre-platform type – not penetrating the sedimentary cover and a platform type – penetrating the sedimentary cover. The faults penetrating the sediment cover are of sublatumic, submeridional, NW and NE trends/directions. More distinctly segregates fault series of Drūkšiai sag (graben) and Anisimovičiai graben. The Drūkšiai graben, the width of which is 3-5 km, is a complicated tectonic structure composed of three belts of 0.5-1.5 km width. The middle part of the graben is uplifted and makes a horst. The faults are more than 20 km long. The amplitudes limiting the horst faults are of 25–55 m and 10–20 m in the north and south parts.
The arc faults of the Anisimovičiai graben split it into sub parallel belts of 0.5-0.7 km width, which descend by steps in the east-north east direction.
The faults are about 10 km long; the amplitude reaches 15-60 m. The total amplitude of the faults from the Lower Silurian crest is about 180 m. The faults of sub-meridional trend dominate in the North Zarasai step and in the east part of the South Drūkšiai uplift. The east part of the North Zarasai step by the faults of sub-meridional trend is split into narrow horsts and grabens with the width of 0.5-1.5 km. The faults are about 5-9 km long; their amplitudes are of 10-20 m. The length of the faults of the South Drūkšiai uplifts delimiting the Apvardai – Prūtas and Mačioniai grabens of 0.7-1.75 km width, is 13-15 km, and their amplitudes – 10-25 m.
The north east and north west trending faults are determined in all tectonic structures (blocks) of Ignalinos NPP. Their length vary from 3-5 to 15-18 km, amplitudes - 15-20 m (*Marcinkevičius et all, 1995*).

Neotectonics

According to morphometric and morphostructural analysis and satellite imaging data a system of a complicated neotectonically active linear zone is distinguished in the region of Ignalinos NPP, where according to the geophysics methods and drilling data or separate faults most of them almost coincide with the tectonic fault zones. Neotectonically active linear zones are of sublatitudinal, submeridional, NW and NE trends however a little bit moved in respect to the tectonic faults (Marcinkevičius *et all*, 1995; Juknelis *et all,* 1990). Narrow paleoincisions are connected with neotectonically active linear zones, which sometimes reach the depth of 200 m (from the pre-Quaternary surface).

Seismic activity

The territory of Lithuania is always considered as a non-seismic region or a region of a very low seismic activity. This is determined by peculiarities of geological structure (the Earth crust of early Precambrian consolidation) and large distance from the active tectonic zones. However the available data show that there were weak or moderate earthquakes. B. Doss from various sources has documented more than 40 strong earthquakes, which took place in the territory of the Baltic countries (according to MSK-64 scale their intensity is now evaluated to 5-7^0). The catalog which he has compiled covers the period of 1616-1911. In 1908-1909 a more significant seismic intensity was observed in all Baltic countries. Most probably it was provoked by a strong earthquake in Mesina, Italy. From that time only one strong earthquake was fixed in 1974 in Osmussare, Estonia (magnitude 4.75). Seismic activity in Lithuania in comparison with Latvia and Estonia is the weakest. Only one strong seismic event is known in Lithuania, which occurred in 1909 in the southeast from Vilnius. However tens of historical earthquakes took place near the border of Lithuania, in the territories of

Latvia and Belarus. According to the seismic-tectonic data (*Suveizdis, 1995; Ilginytė, 1998*) in Lithuania and neighboring territories in the zones of potential earthquakes, earthquakes with the magnitude up to M_{max} = 4.5 generating up to 7º (MSK-64 scale) vibrations in the epicenter of earth surface are possible. According to V. Ilginytė (*Ilginytė, 1998*) the intensity of earthquakes in the surrounding areas of Ignalina nuclear power plant may reach magnitude 4.5. However this data about the intensity of earthquakes and strength is not comprehensively and scientifically approved and therefore while accumulating new research data or over interpreting the available one the assessment of seismic activity in future may change. Lake Drūkšiai is the intersecting place of neotectonically active faults. Currently according to the available data the Lithuanian Geological Service assesses that the territory of INPP belongs to the 6 degree (MSK-64) calculable level of earthquake and the maximum calculable earthquake level in Lithuania can be up to 7 degrees (MSK-64). Considering the tectonic conditions in the part of the region to the south from INPP the levels of earthquake should be lower.

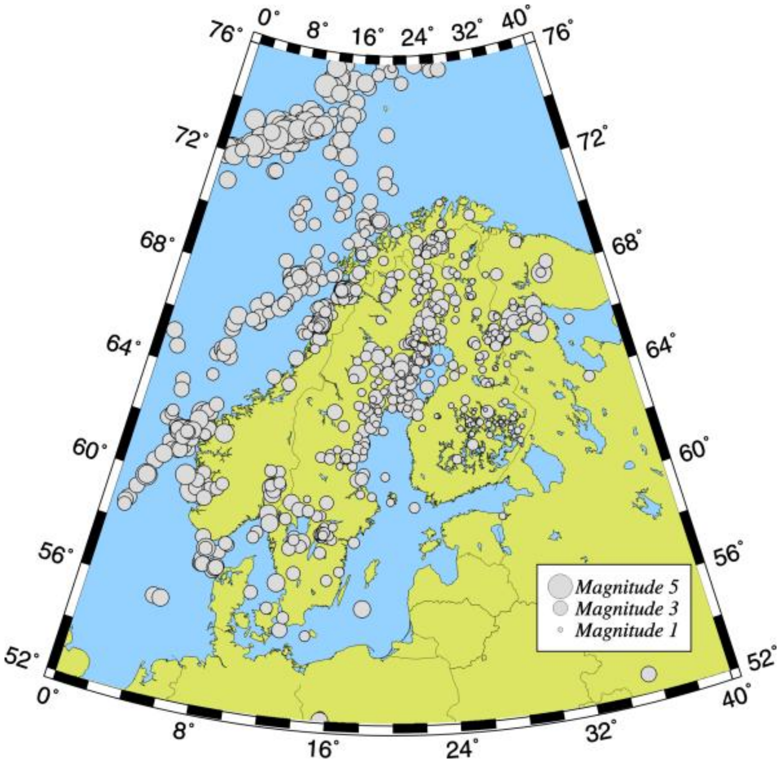


Fig. 4.1.5.7 The approximate cover of a regional seismic catalogue of Institute of Seismology of University of Helsinki and tectonic events fixed in this catalogue in 1991-2002 (Pačėsa, 2004)

Engineering geological conditions in the region

According to the data of engineering geologic investigations edge glacial formations (moraine loams and sandy loams) of Baltija sub suite of Nemunas Fm of Upper Pleistocene comprising the bigger part of a hilly region surface dominate in the surface. Single hills and their massive are deposited from varigrained sand and gravel lentils. Some crests of hills or surface declines are covered by a clay layer with a thickness of 2.4 m. Holocene sediments –alluvium, diluvium and peat are dispersed in the surface of the entire territory.

According to the 1:500 000 scale data of engineering geologic map fluvioglacial fine and dusty sand of edge formations of Baltija sub suite belongs to a strong powdery, and coarse and medium-coarse sand and gravel and gravely sand - to a very strong powdery soil of engineering geologic subgroup. Conical strength of fine and dusty sand reaches 10 MPa,

density changes from 1.79 Mg/m3, when Sr ≤0.8, up to 2.05 Mg/m,3 when Sr >0.8. Conical strength of coarse and medium-coarse sand reaches 11.2 MPa, density – 1.89 Mg/m3, when Sr ≤0.8. Conical strength of gravel and gravely sand reaches 14.8 MPa, density changes from 1.89 Mg/m3, when Sr ≤0.8, up to 2.06 Mg/m3, when Sr >0.8. Moraine loam and sandy loam of edge formations of Baltija sub suite belongs to cohesive soils of medium strength of engineering geologic subgroup. Conical strength of loam and sandy loam comprises 2.5 and 2.6 MPa respectively, density – 2.21 and 2.20 Mg/m3. Conical strength of fine and dusty, coarse and medium-coarse sand, as well as gravel and gravely sand of edge formations of Baltija sub suite respectively comprises 10.2, 11.3 and 12.4 MPa, density comprises 1.62, 1.77 and 1.91 Mg/m3, when Sr ≤0.8. Moraine loam of Baltija sub suite belongs to the engineering geological subgroup of cohesive strong soils. Its conical strength reaches 4.7 MPa, density – 2.26 Mg/m3.
Ground water usually occurs in 2 m depth, rarely - in 2.5 m depth. Aeration zone is composed of moraine loam and sandy loam.

Pollution of resources of the region

Considering the available geological mapping data it may be stated that a complicated geological and geomorphologic structure is typical to a region in the south of Lake Drūkšiai. Due to dominating sandy surface sediments and broken relief, poor protection of underground water is typical to the region, i.e. the conditions are beneficial for the pollution of geological environment. According to the Lithuanian Geological Survey, data of State Information System on Focuses of Geological Environment Pollution there are about 230 types of potential pollution focuses of geological environment in Ignalina region. The most hazardous are considered the following: 13 from 29 pesticide warehouses, non-operating petroleum base, some water cleaning equipment which do not operate or have to be repaired, some of non-operating and deserted farms. Ignalina nuclear power plant is also ascribed to the potential pollution focuses. Considering the comparatively rare net of pollution focuses in comparison with other regions it may be stated that underground resources are not polluted.

Valuable properties of the underground resources, their suitability for the planned economic activity

There are no solid mineral deposits and valuable protected geological objects in the investigated alternative grounds and their surroundings.

APVARDAI SITE

Peculiarities of the structure of the underground resources

Geomorphologic conditions

Apvardai site covers a massive of small low moraine hills from the west and east surrounded by flat depressions, which formerly were marshy, but now are drained. The relief declines towards the trough of Lake Apvardai (from 148-147 m up to 144 m of the absolute height).

Quaternary sediments

According to data of geological investigations limnoglacial sediments of Baltija stage final glacier - varigrained sand (medium-grained dominates) lies in the depth of 8-10 m (Fig.4.1.5.8).Under it lies enriched moraine (g II md) of Middle Pleistocene Medininkai

glacier with large clods of sand. The surface of the main hill is uneven. According to the results of drilling works performed by GROTA UAB at Apvardai site the geological section comprises moraines of the Baltija and Grūda stages laying on the fluvioglacial and glacial (moraine) formations of the penultimate Medininkai glacier. Some hills of the massive are of a kames type and are deposited from moraine sandy with sandy veins of a lighter composition and lens of moraine loam in the depth of up to 2-5 m.
In comparison to Galilaukė site, the geological structure of Apvardai site is more complicated and more changeable.

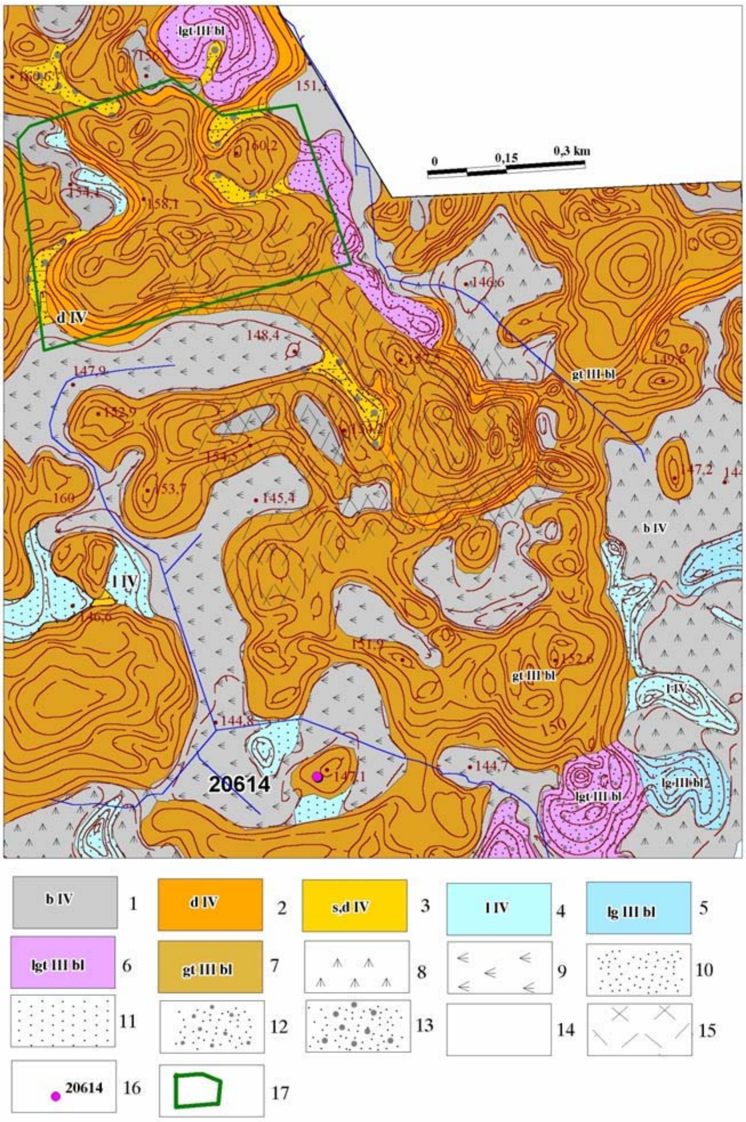


Fig. 4.1.5.8 Geological Quaternary map of Apvardai area (*Identification ..., 2004*) Age and genesis of sediments: Holocene: 1- Bog sediments, 2- Slope sediments, 3- Drifts of surface outwash, 4- Lacustrine sediments; Baltijos stage of the last Nemunas glacier, 5- Limnoglacial (near the glacier basin area) sediments, 6- Kame sediments, 7- Glacial (moraine) formations of the edge of a glacier; Lithology: 8- Low-moor peat, 9- Unidentified moor peat, 10- Very fine sand, 11- Fine sand, 12- Various sand, 13- Gravely sand, 14- Moraine sandy loam, loam, 15- Technogenic ground (clayey, peaty, varigrained sand); Other signs: 16- Drills, 17- Place of a site.

Geophysical investigations of Apvardai site

Investigations of electrical tomography at Apvardai site are performed along two profiles (Fig. 4.1.5.9) using the system of electrical tomography *CAMPUS Resistivity Imaging System.* The method is used for solving of various geological tasks: it helps to assess the structure of the upper part of a geological section according to the change of electric properties of sediments.

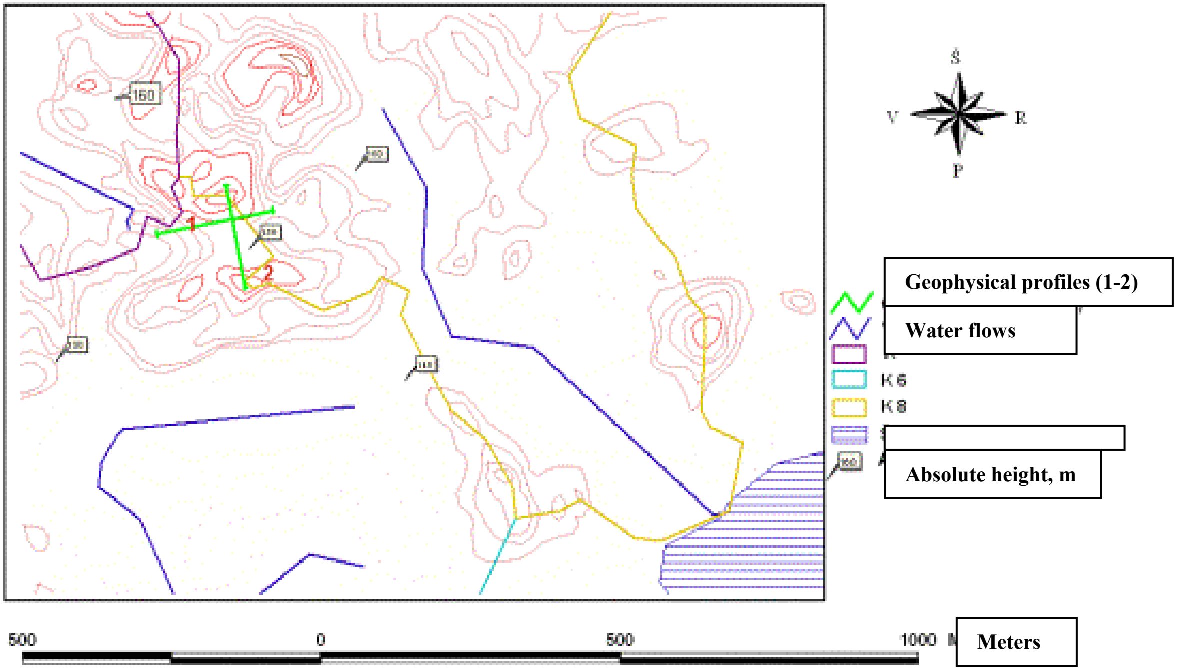
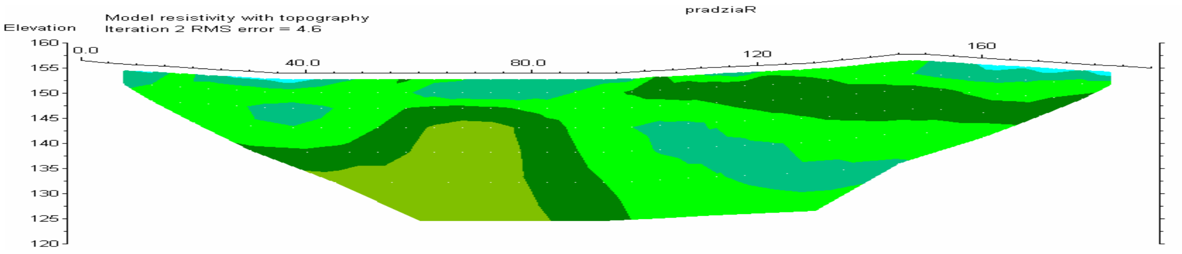


Fig. 4.1.5.9 Geophysical profiles at Apvardai site

Different situation than in Galilaukė site (4.1.5.14, 4.1.5.15) is seen in the geoelectrical models (Fig. 4.1.5.10) of Apvardai site. Here the sediments of higher resistance and more sandy than in Galilaukė site lie in both profiles. Sand-gravel lens segregates at the north end of the 2nd profile.

Profile 1



Profile 2

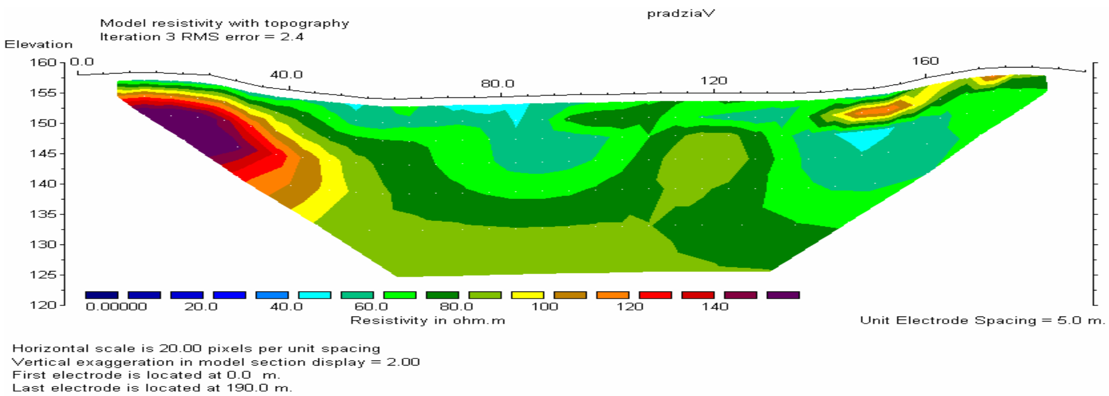


Fig. 4.1.5.10 Geoelectrical models with topography along profiles 1 and 2 at Apvardai site (see profile lines in Fig. 4.1.5.9)

Seismology

There are no specific data on seismic conditions of Apvardai site however the site is ascribed to the region of seismic activity of the Ignalina NPP, which is described in detail in the previous chapter analyzing the entire region. Currently, according to the available data it is admitted that the 6 degree (MSK-64) calculable level of earthquakes is in the territory of INPP and the maximum calculable earthquake level can reach up to 7 degrees (MSK-64). Considering the tectonic conditions of Apvardai site in the south from INPP, the level of earthquakes should be lower.

Engineering geological conditions

Large-scale relief uplifting and loamy soils and sloping land improvement channels form beneficial conditions for a quick surface run-off. However a closed land improvement channel in the NE edge and erratic sandy loam soils decreases the intensity of slope run-off and increases the possibility of the surface water infiltration. Lake Apvardai near the site determines a quick surface water run-off. Apvardai site is distinguished by a fine hilly moraine relief, which on the west and east sides is surrounded by flat-bottomed drained depressions. The site surface up to 3-5 m deep is composed of moraine loam or sandy loam. The section varies in depth: various lentils of 3.5 m thickness or gravely sand and inter strata are found in the moraine. Surface depressions are swampy, where the thickness of peat of some of them is 1-3 m. The ground water level is 0.5-3.0 m deep from the surface in the site. The aeration zone is composed of moraine loam and sandy loam. The hills in the site territory are composed of moraine sandy-loam with sandy veins of a lighter composition and moraine loam lentils. The operating surface of a water bearing complex of the Upper-Middle Devon in the east side of the site is protected and in the west part is conditionally protected against the surface pollution. Geological processes are not provided in the territory of the site. Though in general engineering geological conditions are favorable for construction the attention must be drawn to the fact that during construction when deepening the basements of engineering buildings below the groundwater level, the water level depression is required. According to the initial assessment of physical-mechanical properties of the soil, probe data of a building, the Apvardai site is distinguished for stable and hard plastic soils of high density what permits to forecast a long-term slope stability.

Pollution of the underground resources of Apvardai site

According to the data of State Information System on Focuses of Geological Environment Pollution of the Lithuanian Geological Survey animal husbandry objects located near the site (~0.5 km north of Lake Apvardai) and industrial, energetic, transportation service objects, objects for accumulation and regeneration of polluting materials located 2.5 km north of Lake Apvardai are ascribed to the potential pollution focuses near Apvardai site.
An increase in the amount of technogenic radionuclide in the soil surface layer samples collected from Apvardai site was not determined.

Pollution of the underground resources of Apvardai site

The discussed sites and underground resources of their surrounding area according to the present knowledge and data do not possess valuable properties. The underground water is well protected against possible pollution.

GALILAUKĖ SITE

Peculiarities of the structure of the underground resources

Geomorphologic conditions of Galilaukė site

Galilaukė site is located on the oblong-shaped flat-topped moraine hill ~600 m southwest of the bank of Lake Drūkšiai. A swampy plain of postglacial lake extending up to the bank of the lake stretches from the foot of this hill by the side of Lake Drūkšiai. A hill extends 16-22 m above this plain. A hill above the intermountain depression at the south-west foot extends ~8-12 m. The south-east trending hill sinks from 163.8 m to the absolute height of 150 m. The south-west part of Galilaukė site up to 3.6 m deep is composed of clayey sandy aleurite on the distribution surface of which the limit coincides with isohypses of 160 m length. Satellite imaging data show that a structure of the hill is monolithic. Special geological investigations confirmed that the hill up to 25 m deep is composed of moraine loam and sandy loam of the last Nemunas and penultimate Medininkai glaciers. A hilly relief of edge-area glacier formations extending north-west from the investigated hill is of a changeable structure.

Structure and composition of Quaternary sediments

The changeable geological structure is determined in the depression extending to the southwest foot. Formerly swampy and now drained depressions at the foot of southwest hill up to 1.5 m deep are filled with lacustrine sediments. This is the micro-stratum thickness of aleurite, clay and very fine sand, the upper part of which (up to 0.6-1.0 m deep) is peaty. Very fine sand laying in the lower part of the section – water-bearing. Lacustrine sediments lie on Baltija moraine (4.4 m deep), which from Grūda moraine of 3.3 m thickness is delimited by inter-strata of ~1 m thickness of water bearing sand. The thickness of water bearing varigrained sand of

Medininkai age lies under Grūda moraine. The northwest slope of the hill is composed of sandier moraine sandy loam than the hill itself. The inter-strata of water bearing sand found at a depth of 5.8 m is water bearing horizon of Medininkai age. Quaternary geology of Galilaukė site is depicted in Fig. 4.1.5.11 and 4.1.5.12.

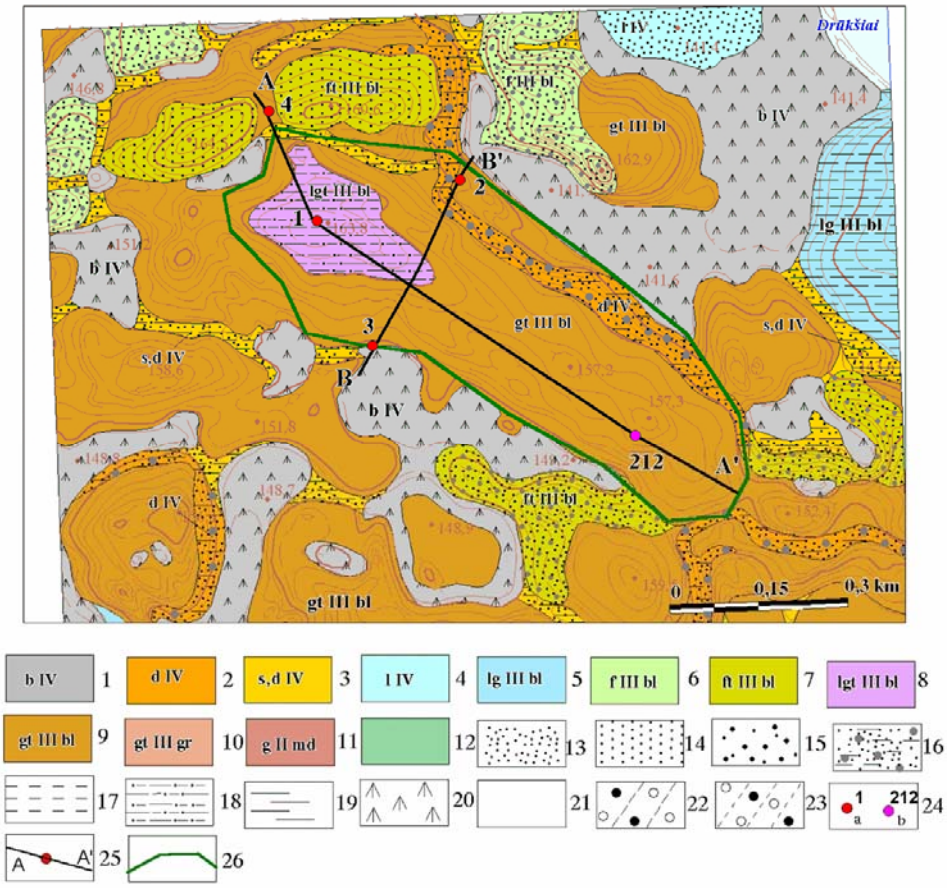


Fig. 4.1.5.11 Geological Quaternary map of Galilaukė area (*Identification …, 2004*) Age and genesis of sediments: Holocene: 1- Bog sediments, 2- Slope sediments, 3- Drifts of surface outwash (solifluction–diluvia), 4- Lacustrine sediments; the Baltijos stage last Nemunas glacier, 5- Limn glacial (near the glacier basin area) sediments, 6- Fluvioglacial (of glacier melting) sediments; 7- Fluvial kame sediments, 8- Limn kame sediments; 9- Glacial (moraine) formations of the edge of a glacier; only in geological sections; 10- Edge glacial formations (moraine) of the Grūda stage last Nemunas glacier; 11- Glacial formations (moraine) of Medininkai glacier, 12- Inter-moraine sediments, Lithology; 13- Very fine sand; 14- Fine sand; 15- Various sand; 16- Gravely sand, 17- Aleurite; 18 – Clay: aleurite, sandy; 19 – Clay; 20 – Peat; 21 - Moraine sandy loam, loam (only on the map); 22 - Moraine loam; 23- Moraine sandy loam, Other signs: 24- Drills: a - drilled during the project works, b- during geological cartography, 25- Lines of geological sections.

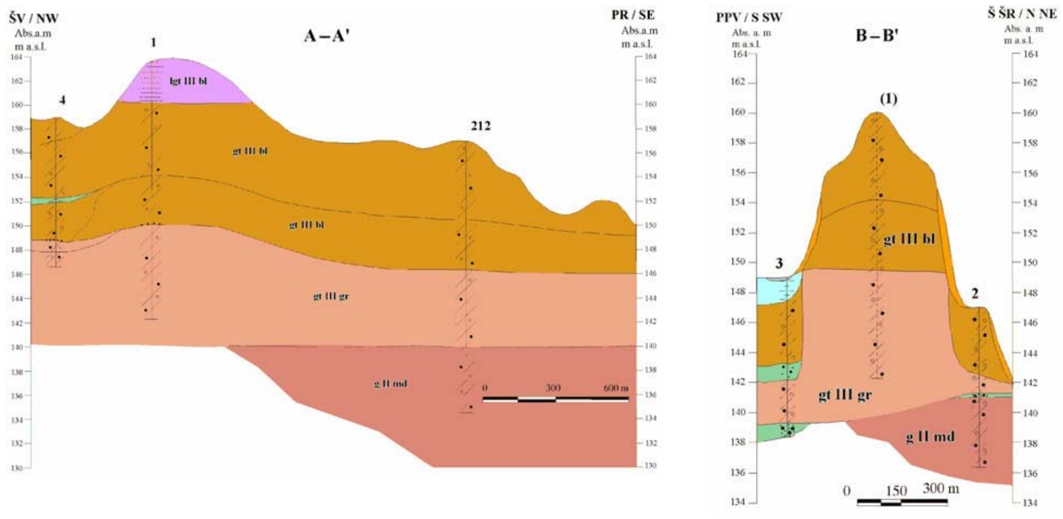


Fig. 4.1.5.12 Geological sections A-A‘ and B-B’ of Galilaukė site

Geophysical investigations of Galilaukė site

Field surveys of electric tomography (ET) were carried out on 4-7 May 2008 in the designed sites for storing of radioactive waste using the electric tomography system CAMPUS Resistivity Imaging System. Investigations at Galilaukė site are performed along 7 profiles (Fig. 4.1.5.13).The data obtained during field surveys were processed and interpreted using the RES2DINV program.

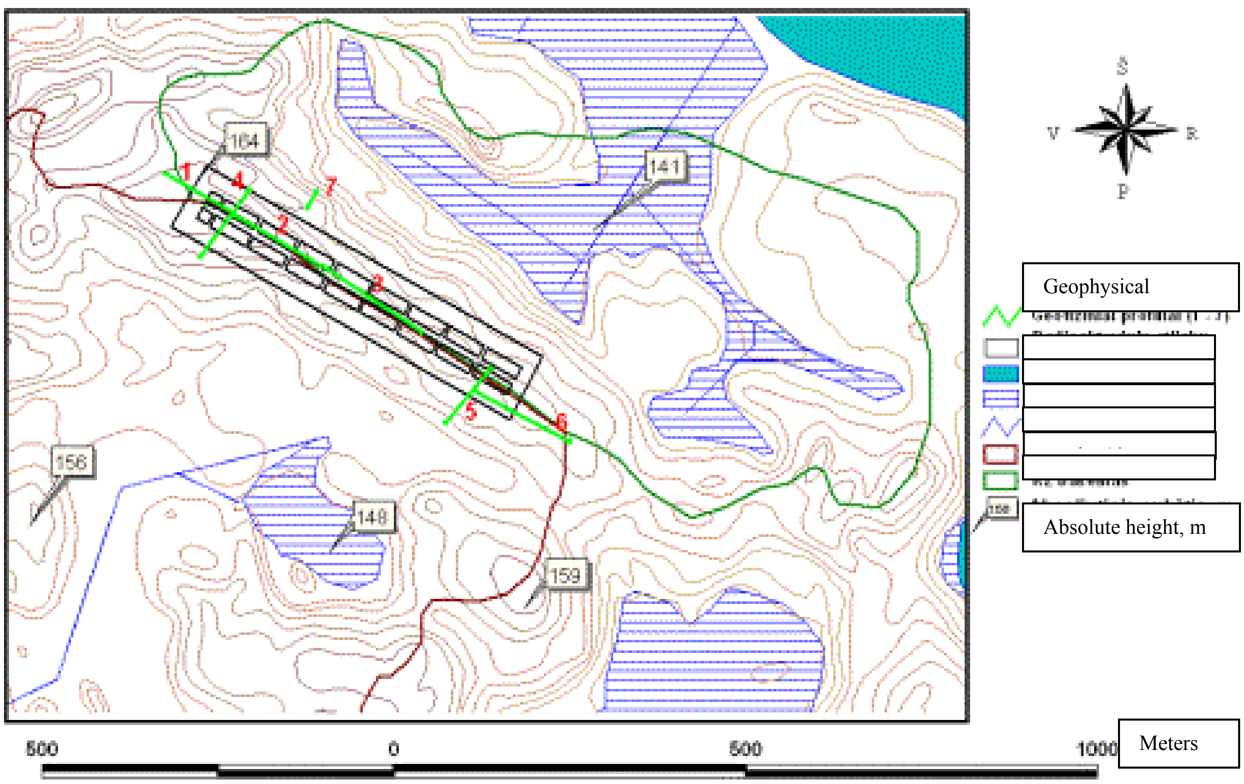


Fig. 4.1.5.13 Geophysical profiles at Galilaukė site

The preliminary geoelectrical models are composed across the profiles using the same scale of electrical resistance (Fig. 4.1.5.14). Since during the field surveys Venner electro prospecting array of 39 electrodes with 5 m distance between the neighboring electrodes was used for all profiles (except profile 7 at Galilaukė site), the length of separate profiles reached 190m, and investigation depth – 29.3 m of the land surface. The length of profile 7 at Galilaukė site reached 37 m, and investigation depth – 6 m of the land surface.

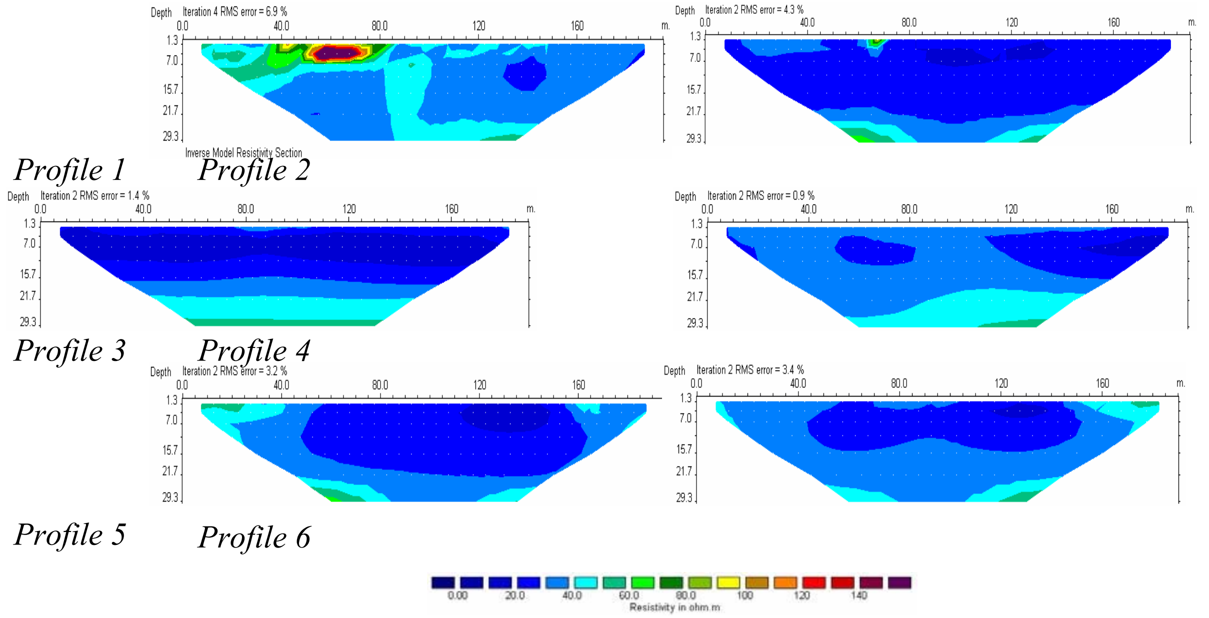


Fig. 4.1.5.14 Geoelectrical models according to the data of electrical tomography across the profile lines 1-6 at Galilaukė site (Numbers on the horizontal axis mean: distance from the profile beginning, on a vertical axis – depth below the land surface, at the bottom – a scale of individual electrical resistance)

Sediments of low electrical resistance not exceeding 60 Ωm characteristic to clayey sediments denominate in all profiles at Galilaukė site. Considering the preliminary geological data it may be stated that in the entire area of Galilaukė site moraine loams lie in the upper part of a section. Only lens of visible sandy sediments of higher resistance are distinguished up to 5 m deep in the upper part of a section at northwest end of profile 1. To have a more comprehensive view about the geological structure of Galilaukė site data of profiles 1, 2, 3 and 6 was joined into one massive and a continuous profile of 910 m length was comprised (Fig.4.1.5.15). Topographic map data was used for the development of this geoelectrical model (as all the rest). After summarizing the data of geophysical investigations it was determined that clayey sediments dominate in a section of the site.

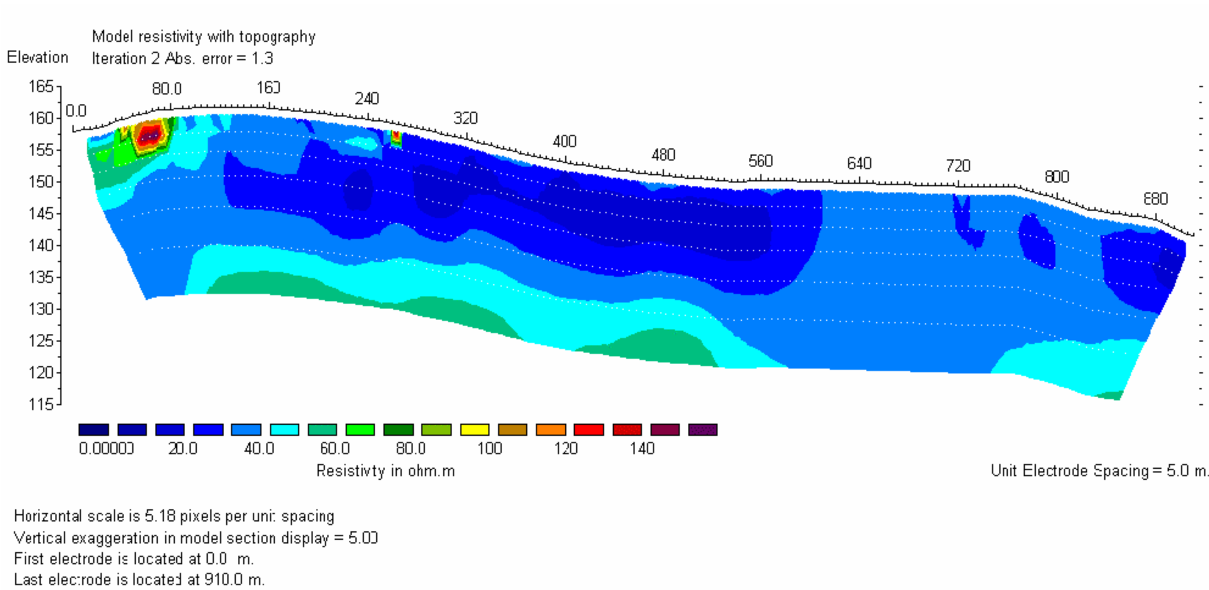


Fig. 4.1.5.15 Joint geoelectrical model with topography across the lines of profiles 1, 2, 3, and 6 (See Fig. 4.1.5.13) at Galilaukė site

Seismology

There are no specific data on seismic conditions of Galilaukė site however the site is ascribed to the region of seismic activity of the Ignalina NPP. Currently according to the available data it is admitted that the 6 degree (MSK-64) calculable level of earthquakes is in the territory of INPP and the maximum calculable earthquake level can reach up to 7 degrees (MSK-64). Considering the tectonic conditions of Galilaukė site in the south from INPP, the level of earthquakes should be lower.

Engineering geological conditions

Large-scale relief uplifting, clayey and loamy soils and the system of land improvement channels form beneficial conditions for a quick surface run-off. Feeder streams near the site of Lake Drūkšiai and the lake itself determine a quick surface water run-off and its high dilution. The foot of the hill in some places is swampy. The operating underground pressure water horizons are protected against the surface pollution. Galilaukė site is distinguished by an unchangeable geological section of the surface and covers one flat-topped moraine hill of 10-15 m height. The hill of up to 30 m depth is composed of semi-solid moraine loam without sand lentils or inter-strata. The depressions of hill's surface are in some places swampy, however now are drained. Different depths of ground water are determined in the boreholes drilled at Galilaukė site: 1st borehole – 19.6 m, 2nd borehole – 2.77 m, 3rd borehole – 1.72 m, 4th borehole – 1.86 m. From lithological point of view the aeration zone is composed of loam and sandy loam.

Active geological processes are not provided in the territory of the site. In general engineering geological conditions are favorable for construction. The attention must be drawn to the fact that during construction when deepening the basements of engineering buildings below the groundwater level, the water level depression is required. According to the initial assessment of physical-mechanical properties of the soil and probe data of a building, the Galilaukė site is distinguished for stable and hard plastic soils of high density what enables to forecast a long-term slope stability, Table 4.1.5.1.

Table 4.1.5.1 Generalized physical-mechanical soil properties of Galilaukė site (according to Identification ..., 2004).

Indicator	**Depth, m**	**Rock**	**Natural humidity, w_n, parts of unit**	**Humidity of fluidity w_L**	**Humidity of elasticity w_p, parts of unit**	**Number of elasticity I_p**	**Indicator of fluidity I_L**
gtIIIbl	3.2-9.6	Rough loam	0.147	0.247	0.126	0.121	0.177
gtIIIbl	3.2-3.3	Coarse sandy loam	0.112	0.151	0.107	0.044	0.114
gtIIIbl	1.6-1.7	Fine sandy loam	0.127	0.257	0.124	0.134	0.022
gtIIIgr	8.5-15.1	Rough loam	0.133	0.199	0.110	0.090	0.262
gtIIIgr	4.7-4.8	Coarse sandy loam	0.11	0.159	0.097	0.062	0.21
gtIIIgr	11.0-21.2	Fine sandy loam	0.138	0.209	0.109	0.100	0.286
gtIImd	8.3-8.4	Coarse sandy loam	0.112	0.164	0.102	0.062	0.161
lgtIII bl	1.8-3.7	Aleurite: sandy, clayey	0.157	0.305	0.135	0.170	0.133
lgtIII bl	1.0-1.1	Clay: aleurite, sandy	0.166	0.316	0.147	0.169	0.112
lIV	0.6-0.8	Aleurite: sandy, clayey	0.166	0.316	0.147	0.169	0.112

Pollution of the underground resources

According to the data of State Information System on Focuses of Geological Environment Pollution of the Lithuanian Geological Survey former animal husbandry objects (not operating) located near the site (~3.2 km southwest of Galilaukė site) are ascribed to the potential pollution focuses near Galilaukė site. Considering the possible environment pollution characteristic to animal husbandry objects it may be stated that only local pollution is possible in their surroundings, which have no impact to Galilaukė site.
An increase in the amount of technogenic radionuclide in the soil surface layer samples collected from Galilaukė site was not determined.

Valuable properties of the underground resources, their suitability for the planned economic activity

According to the current knowledge and data the discussed sites and the underground resources of the surrounding area do not posses valuable properties. The underground water is well protected from the possible pollution. Galilaukė site is characterized for almost unchangeable geological structure and covers one flat-topped moraine hill of 10-15 m height, which up to 30 m depth is composed of semisolid moraine loam without sand lens or inter-strata. The site is characterized by stable soils of high density and therefore slope stability may be forecasted. Large-scale relief uplifts, clayey and loamy soils and the system of land improvement channels form beneficial conditions for a surface run-off and the feeder streams near the site of Lake Drūkšiai and the lake itself determine a quick surface water run-off and its high dilution. Due to these reasons Galilaukė site is suitable for radioactive waste burial ground.

STABATIŠKĖ SITE

Peculiarities of the structure of the underground resources

Geomorphologic conditions

The relief of the territory of the site is hilly: several low hills of oblong-shape, which are delimited by depression, part of which is swampy, prevail (*Račkauskas V., ..., 2005*). The maximum absolute height of the hills where it is provided to establish the burial ground is 160.09 m. The lowest absolute height of the entire territory is in its northeast part, in a swamp, and reaches 146.84 m. In many places during the last 30 years the lowest relief forms have changed due to waterlogged territories (technogenic soil embankments, beaver dikes).
The maximum leaning angle of hill slopes is 7^o, predominating - 5^o (*Taminskas J., 2005*). According to topographic map M1:2000 in the local segments of investigated hill slopes, especially where dips approach the hills, the calculated leaning angle reaches $14\text{-}20^o$. Such dips – the old dips covered with forest, are found near the north and east side of a central hill. The bigger part of a site, except in some places peaks of the hills and slopes, is covered with forest and bushes. The inhabitants are moved out of the said area due to construction works of Ignalina NPP (*Račkauskas V., ..., 2005*). The remainder homesteads, which are retraced according to the old topographic maps, are also destroyed – the area is prepared for the forest planting.

Quaternary sediments

Moraine sediments of edge formations of the Baltija stage last glaciations (gtIIIbl) lie in the surface of the hills of the site territory within the stratum of 2.4 m-4.7 m thickness. They are composed of reddish-brown moraine sandy loam, rarely the brown one with the strata of fine-grained, lightly brown, clayey sand of 0.1-0.15 m thickness locally prevailing in the southeast part of the territory and with sand of 0.05-0.1 m thickness and aleurite lens in the north part of the territory. The strata of moraine sediments of edge formations of the Baltija stage in the depressions of the territory relief between the hills get thinner up to 0.7-1.1 m thickness and in places it is even not available. Moraine sediments mentioned in these depressions are composed of moraine loam, which turns into greenish-brown or grayish-brown color.

Limnoglacial sandy, dusty sediments and fluvioglacial sandy sediments of the Baltija stage(lgIIIbl) last glaciations – grayish-yellow, fine-grained, lightly-yellowish-gray fine-grained, aleurite sand, yellowish-brown aleurite, yellow or yellowish-brown, fine-grained, in places loamy, sand – locally prevailing of 0.3-1.8 m thickness in many places lie at the surface of the hills on the moraine sediments of edge formations of Baltija stage.

Locally prevailing *Holocene swamp sediments (bIV) and lacustrine sediments (lIV)* of 0.1-5.2 m thickness lie in most places of the relief depression of the site. *Diluvial sediments (dIV)* of 0.7 m thickness occur in some places at the foot of the steeper slopes.

Somewhere occur *technogenic sediments (tIV)* with the thickness of 1.0-1.5 m. Swamp sediments are composed of peat of brown to black color, well decomposed, rarely badly and on an average, and black, well decomposed sapropel (sludge); lacustrine: greenish-gray, gray, dark grey, especially fine-grained aleurite, in places with organic impurities, sand and lightly gray with organics, in places sandy, aleurite; deluvial: brown, sandy, clay with gravel; technogenic: poured brown moraine sandy loam. Below the said Holocene sediments and sometimes even on its surface in the relief depressions locally occur areas of *fluvioglacial sandy sediments of the Baltija stage (fIIIbl)* of 0.5-1.1 m thickness, which contrary to the hills', are composed of greenish-gray, gray, lightly-yellowish-gray, brownish-gray, grayish-brown and brown, fine-grained, very often aleurite, rarely loamy, in places with rare gravel, sand (Fig. 4.1.5.16).

Moraine sediments of Grūda stage (gIIIgr) lie almost everywhere in the hills below the moraine sediments of edge formations of Baltija stage and in the relief depressions - below fluvioglacial sandy sediments and Holocene swamp sediments. Their thickness reaches 1.8-8.1 m, usually 4-6 m (Fig. 4.1.5.17, 4.1.5.18). These sediments in the hills are composed of brown loam; rarely of brown moraine sandy loam with the inter-strata of brownish, medium-grained sand of 0.7 m thickness and sandy loamy aleurite of 0.4 m thickness locally extending to the north part of the territory. The inter-strata are found in the lower part of the said moraine stratum near the bottom of the stratum. In the relief depressions, especially in the swamps, the color of moraine sediments of Grūda stage very often changes. A poor consistency is characteristic to sediments, more often murrain sandy loam is found. These sediments are composed of moraine loam and sandy loam: grayish-brown and brown, rarely greenish-gray, gray and brownish-grey. Sometimes the inter-strata of 0.5 m thickness of loamy fine-grained sand occur.
Fluvioglacial sandy sediments (fIIIgr) and limnoglacial sandy dusty sediments (lgIIIgr) of Grūda stage occur below the moraine sediments of Grūda stage. Fluvioglacial sediments are composed of light brown, gray, brownish-gray, rarely light-yellowish-gray, and grayish-brown, brownish, yellowish-brown, varigrained, coarse grained, often gravely, medium-grained, rarely fine-grained sand and dark brown, brownish gray gravel. The thickness of separate lithology layer reaches 0.8-7.8 m, more often it reaches 3-5 m thickness. Limnoglacial sediments occur rarely, they are composed of brown, yellowish-brown, yellowish-gray, reddish-gray, fine-grained and lightly-yellowish-gray, fine- grained in particular, aleurite, sand with loamy, brownish-gray aleurite strata (up to 0.2 m thickness) and

streaks (up to 2mm thickness), and brown, sandy, loamy aleurite. The thickness of stratum reaches 0.2-2.6 m, more often – 0.2-0.4 m. The varigrained fluvioglacial sands prevail.

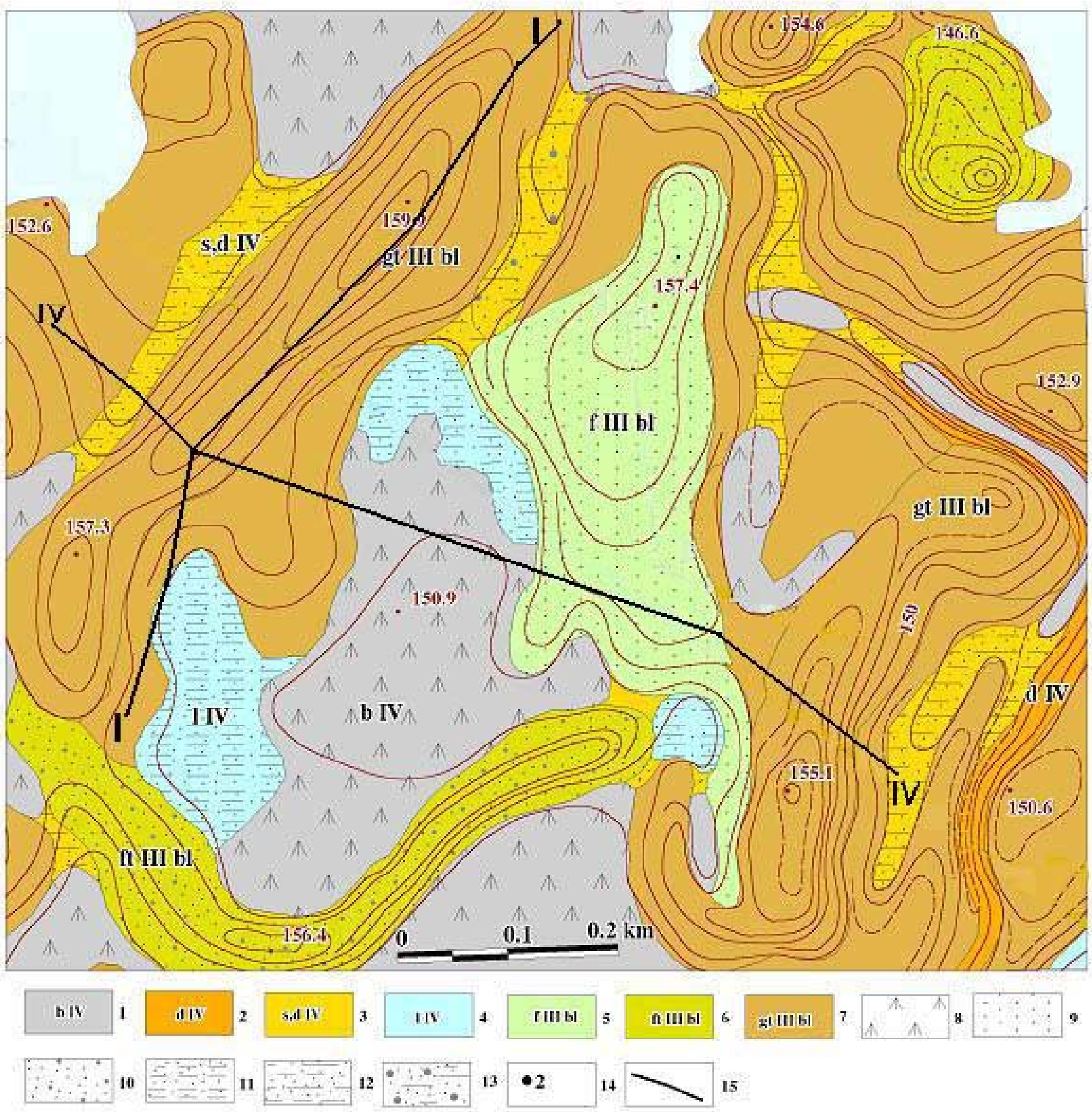


Fig. 4.1.5.16 Geological map of Stabatiškė site (Original scale 1:10 000, author R. Guobytė, 2005).

Age and genesis of sediments

Holocene: 1 – Bog sediments, 2 – Deluvial sediments, 3 – Solifluction-deluvial sediments, 4 – Lacustrine (limnic) sediments;

The Baltija stage last (Nemunas) glacier: 5 – Fluvioglacial (melting glacier) sediments, 6 – Crack formations of edge glacier (Esker and kame sediments), 7 – Glacial formations or moraine of edge glacier (moraine sandy loam);

Lithology: 8 – Peat, 9 – Fine sand, 10 – Various sand, 11 – Aleurite sand, 12 – Aleurite-loamy sand, 13 – Various loamy sand with rare gravel, 14- Borehole; 15- Section line.

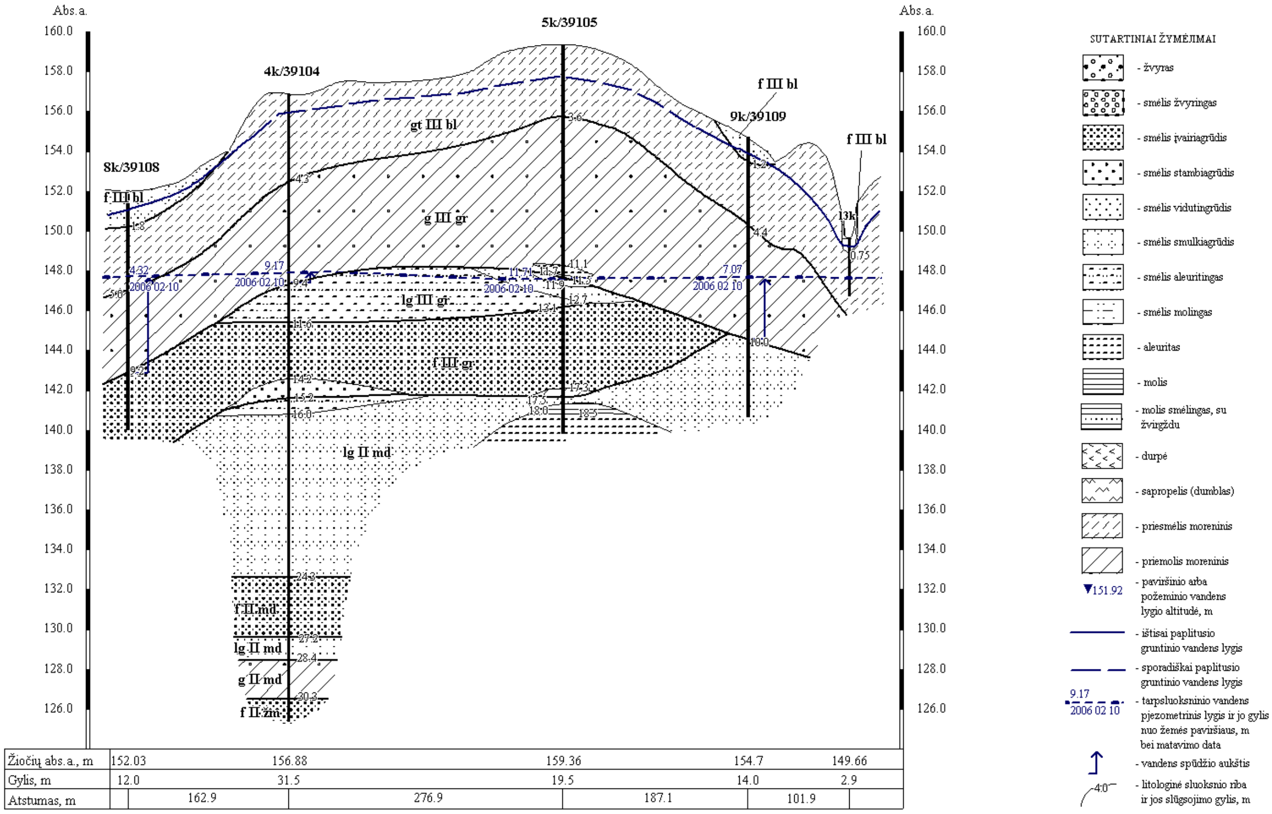


Fig. 4.1.5.17 Geological section I-I (Authors: V. Račkauskas et all, 2005)

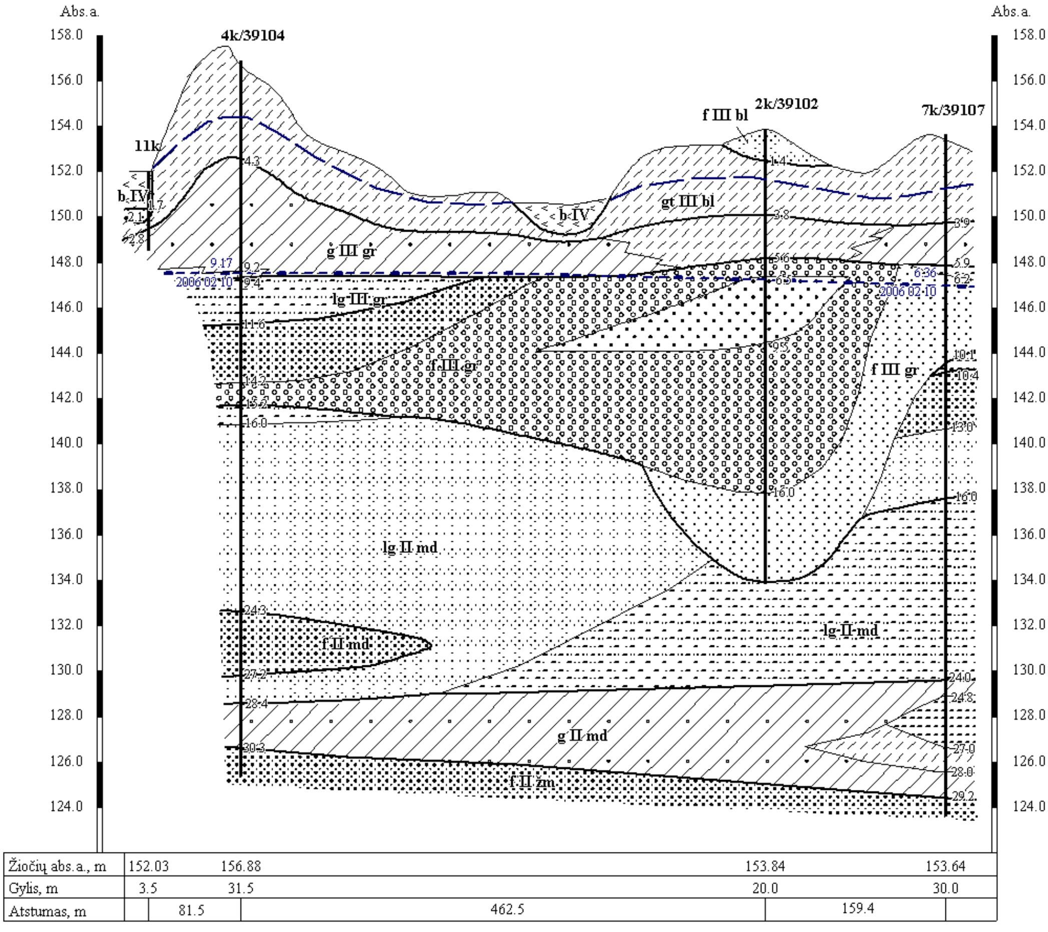


Fig. 4.1.5.18 Geological section IV-IV (Authors: V. Račkauskas et all, 2005).

Limnoglacial sandy dusty and loamy sediments of the Middle Pleistocene Medininkai stage glaciations (fIImd) with rare *fluvioglacial sand strata* up to 2.9 m thickness occur below fluvioglacial and limnoglacial sediments of Grūda stage. Limnoglacial sediments are composed of brown, lightly-yellowish-gray, rarely yellow, fine-grained, sometimes aleurite and gray, fine-grained in particular, aleurite sand with aleurite inter-strata (up to 0.1 m thickness) and brown, aleurite loam and sandy aleurite. The thickness of fine-grained sand stratum reaches 0.5-8.3 m, fine-grained in particular, sometimes fine-grained, aleurite sand – 0.8-8.0 m, and sandy aleurite – more than 1.0 m. The thickness of all lithological species is very changeable.

Limnoglacial sediments of the Medininkai stage glaciations grounds G*lacial sediments of the Medininkai stage glaciations (gIImd)* (the second thickness of moraine soils of the land surface), which mostly are composed of brown moraine loam (in places up to 0.5 m thickness), rarely – brown moraine sandy loam with single lens of brownish-gray aleurite (up to 2.2 m thickness). The inter strata of brown clay (up to 0.1-0.15 m thickness) are found in the said aleurite lens. The total thickness of moraine stratum varies from 1.9 to 5.2 m.

Fluvioglacial - lightly-yellowish-gray, grayish-brown, varigrained, of medium density - *sand (fIIžm)* of the *Middle Pleistocene of Žemaitija stage* occur below the moraine sediments of Medininkai stage glaciations. It is drilled up to 0.8-1.2 m.

Lying conditions of Quaternary sediments are illustrated by geological- hydro geological sections (Fig. 4.1.5.14, 4.1.5.15). The sections demonstrate that in the hills on the land surface or below the insignificant covering of non-moraine sand, aleurite and other sediments the stratum of moraine sediments of Baltijos and Grūda stages occurs, the total thickness of which changes from 4.7 m in the central hill up to 11.5 m in the north-west hill. This moraine thickness in the relief depressions is thinner and the total thickness of peat, sapropel, aleurite sand and other sediments occurring above it in places reaches 5.2-5.7 m.

Fluvioglacial sediments of Grūda stage with single, usually not thick inter strata of limnoglacial sediments (aleurite sands, aleurite) occur in the upper part of more rough aqua glacial sandy-clayey sediment thickness *(aq IIIgr-IImd)* of inter moraine of Grūda and Medininkai stages glaciations, and limnoglacial sediments of Medininkai stage occur in the lower part, which is distinguished for clean, fine-grained, without gravel admixture, and very fine-grained, most usually aleurite sands, with common, but not thick inter strata of clay and aleurite. The total thickness of the said aqua glacial sediments changes reaches 18.1-19.0 m. The thickness of sediments of a larger fraction occurring in the upper part varies from 5.8 to 14.4 m, and the fine grained sediments with aleurite and clay admixture and inter strata or streaks occurring in the lower part preliminary compose a layer of total 8.0-13.2 m thickness. The crest of Medininkai stage glaciations lies at a depth of 24.0-28.4 m, i.e. in the absolute height of 128.48-129.64 m.

Hydro geological conditions

During the eco geological investigations two water-bearing strata were found at a depth of 20-30 m in Stabatiškė site: 1) The upper – of ground (and/or above lentils) water and 2) Deeper – of inter stratum water.

Ground (the first of the land surface) water accumulates in the strata and inter strata of peat, sand, poured soil and sandy loam and lentils existing in the loam and in more permeable cracked or decayed zones. Ground water prevails in the lower parts of the relief. Whereas in the highest parts of the territory relief it was found not everywhere since sometimes the ground water flows through the more water-permeable sediment zones and does not accumulate at specific points or accumulates only during separate (rainy) seasons.

The ground water level in the lowest part of the territory relief was found of the land surface up to dozens of centimeters deep. In the upper parts of the territory the ground water level was up to 3.7 m deep below the land surface. The highest sporadically prevailing ground water altitude near the hills is in the borehole of 152.5 m 14k.

The highest place where ground water occurs is the hills. From the hills it filtrates down into ravines and swampy places. Around the hills the direction of ground water is radial, i.e. it filtrates into all sides from the hills. However the general tendency of the relief is in the north-east part (towards Lake Drūkšiai), what determines the prevailing direction of surface and underground water flow. Ground and surface water (swamps, bogs) is hydraulically related.
The investigated territory mostly is covered by clayey rocks, i.e. low water- permeable rocks. More permeable sediments (peat, sand) are sporadically spread. Therefore the average speed of ground water filtration should be very low – up to several centimeters per day.
The second water bearing stratum of the land surface in the investigated territory occur between two water-impervious clayey strata in the water-permeable Quaternary thicknesses of the aqua glacial sediments of the Upper Pleistocene of Grūda Fm – Middle Pleistocene of Medininkai Fm (sand of various roughness, gravely sand, dusty sand, gravel). ***The inter-stratum water level*** during the investigation was at a depth 4.32-11.71 m of the land surface, or in the height of 147-148 m above the Baltic Sea level. The deepest water level of the land surface is in the hills, and the shallowest level – in the lowlands. In the bigger part of the territory water is without pressure – its level in places coincides with the crest of sandy stratum. In lower places water is under pressure, i.e. its piezometric level in the boreholes rises from dozens of centimeters up to several meters above the crest layer.
The altitudes of inter-stratum water decreases in the north east part of the territory towards the pond. It demonstrates that inter-stratum water as a part of ground water filtrates towards the said pond. The level altitudes of inter-stratum and surface (pond's) water in the north east angle of the territory coincide. The surface and inter-stratum water of the pond separates the low water-permeable stratum of moraine loam, the thickness of which reaches several meters. Therefore it may be stated that inter-stratum water in the north east part of the territory while permeating through the thin stratum of loam or its permeable parts, should discharge in part, i. e. "feed" the said pond.

According to investigation data of mechanical soil composition (granulometric analysis) the coefficient of rock filtration of water bearing layer (the upper part) changes from 4.6 to 27.2 m/day. As it was mentioned the sandy fractions in deeper layers become smaller and a coefficient of filtration is smaller too. The generalized filtration coefficient of water bearing rock layer is about 19 m/day. As it was mentioned above the layer is composed of sediments of various roughness, therefore their coefficient of filtration changes in both directions – vertical and lateral.

Underground nourishment and drainage conditions are rather steady due to good filtration peculiarities of water bearing stratum and steady drainage contour of Lake Drūkšiai; therefore water-level changes in the course of a year are not significant in the site.

Water bearing stratum is confined by a brown moraine loam and sandy loam of Medininkai Fm, which from the hydrodynamic aspect is a relative confining layer.

Seismology
Stabatiškė site is ascribed to the region of seismic activity of the Ignalina NPP. Currently according to the available data it is admitted that the 6 degree (MSK-64) calculable level of

earthquakes is in the territory of INPP and the maximum calculable earthquake level can reach up to 7 degrees (MSK-64) assessing soil resistance to dynamic load.

Engineering geological conditions

The relief of the site surface determines the favorable conditions for surface run-off. Engineering geological conditions are characterized during soil investigations, which will be the ground of the provided object. The basis of the radioactive waste burial ground is the depth of the Quaternary sediments of up to 30 m thickness. Powdery, sandy, cohesive clayey and compressible biogenic soils compose the engineering geological section (up to 20- 30 m deep) of Stabatiškė site.

The strength of cohesive clayey soils determines their consistency, and powdery sandy – their density. *Moraine soil of edge formations of the Baltija stage (gtIIIbl)* last glaciations occurring on the land surface of the site is hard plastic, rarely semi-solid or soft plastic. *Limnoglacial dusty soil of the Baltijos stage (lgIIIbl)* last glaciations – fine sand and *fluvioglacial dusty soil (fIIIbl)* - fine or clayey sand of medium density.

During the previous investigations while drilling (Račkauskas V., 2005; Marcinkevičius V. 1995) organogenic (H*olocene swamps) (bIV)* compressible soils (peat and sapropel), the thickness of which reach 3.3 m were found. According to the new drilling data it was determined that these soils lie in many places of the relief depressions of the investigated site and comprise the strata of 0.1-5.2 m thickness. Sandy-dusty soils formed by *lacustrine sediments (lIV)* are spread in some places of relief depressions. It is a very fine dusty sand of medium-density and aleurite (dust). *Soils of deluvial origin (dIV)* are composed of soft plastic clay with sand and gravel admixture.

Moraine soil of Grūda stage *(gIIIgr):* moraine soil in the hills is hard-plastic and semi-stable, sometimes soft-plastic, and its consistency in the relief depressions is poorer – usually soft-plastic, and in contact with the peat swamp - runny plastic. *Fluvioglacial dusty (fIIIgr)* and *limnoglacial dusty (lgIIIgr)* soils of *Grūda stage:* sand of various roughness and gravel are of medium density.

Limnoglacial soils (lgIImd) *of the previous glaciations (*Medininkai) stage: sand of medium roughness, sometimes dusty, of medium density and thick sand, sometimes soft and plastic clay. The glacigenic *(gIImd)* soils of this stage (the second depth of the land surface of moraine soils) is hard-plastic (in places - soft-plastic) moraine loam, rarely – soft-plastic moraine sandy loam with single lens of hard-plastic aleurite. *Fluvioglacial sand (fIIžm)* of various roughness and medium density of *Žemaitija stage* lies in the lower part of the engineering geological section.
The slopes of the site hills are steady, unfavorable geological process does not take place there, and the depression of the central part of the site is becoming swampy. The generalized parameters of physical-mechanical properties of the site soils are given in Table 4.1.5.2.

Table 4.1.5.2 Generalized physical-mechanical properties of the soils of Stabatiškė site (Taminskas et all, 2005)

Indicator, Lithology	Cohesion *c, MPa*	Inner friction angle *φ, degree*	Deformation module *E, MPa*	Soil density *ρ, Mg/m³*	Indicator of fluidity *I_L*	*Notes*

l IV (Fine sand)			12	1.7		Weak
gt III bl (Light loam)	0.028	21	18	2.16	0.58	
gt III bl (Hard loam)			46	2.18	0.25	
f III bl (Dusty)		26	14	1.89		
f III bl (Fine)		32	30	1.7		
f III bl (Medium-roughness)		34	40	2.09		Strong
g III gr (Hard loam)	0.035	29	31	2.24	0.058	
f III gr-bl (Coarse/rough sand)			46	2.07		

The most important engineering geological problem of the sites is the risk of dusty sand dilution under dynamic load. Considering the results of dynamic probe (V.Račkauskas, ..., 2006) dilution of sandy soils under dynamic load is practically impossible – sand is thick or of medium density and is distinguished by good cohesion. Physical mechanical features of surface sediments of the hills were assessed suitable for the equipment of burial ground of radioactive waste. Peat soils locally spread (peat and sapropel) are especially compressible and are not suitable for building foundation.

Pollution of the underground resources

Two dumping grounds near Stabatiškė site (1.5 km southwest is the dumping of *Visagino būst*as, 500 km southeast is a dumping of construction waste of Ignalina NPP), 1 boiler house, 1 petroleum base, reactors of nuclear station and other objects (1 km north) are ascribed to the potential focuses of pollution. The site is surrounded by roads; the railway track is at a distance of 700 m from the projected burial ground. Visaginas waste water cleaning equipment is about 0.5 km southwest of the site. Waste piping (southwest) is installed near the site, where waste from the nuclear power station gets into cleaning equipment. It may be stated that Stabatiškė site is in the territory of potential complex pollution.

Valuable properties of the underground resources, their suitability for the planned economic activity

The discussed sites and the underground resources of their surrounding area according to current knowledge and information do not possess valuable properties. The operating drinking underground water is well protected from possible pollution.

4.1.6. Biological Diversity

<u>GALILAUKĖ SITE</u>

The area being analysed is located in the agricultural land plot. Currently, there are no trees or bushes on the hill being examined, and grass vegetation of cultural meadows and grasslands occupies the whole hill and its slopes. Green crops sown some time ago that dominate this area are as follows: alsike clover *Trifolium hybridum*, white and yellow sweet-clovers *Melilotus albus*, *M. officinalis*, and orchard grass *Dactylis glomerata*. The following varieties found in abandoned arable land are less abundant but more widely spread: red clover *Trifolium pratense*, yellow chamomile *Anthemis tinctoria*, and scentless chamomile *Matricaria maritima*. Those are the species that are very common in Lithuania. The cultural meadow of the hill displays certain features of naturalisation: tutsan, spreading bellflower, cornflower, etc. are spreading in this area. No rare units of flora have been found there yet. The lowland (swamp) situated in the northern base of the hill is abundantly overgrown with willow bushes and sedges and is covered by water. No varieties to be protected have been found there yet.

A wide descent located in the south of the hill is covered by thrifty varieties that are characteristic of abandoned homesteads and soil such as moxa herb *Arthemisia vulgaris*, stinging nettle *Urtica dioica*, coltsfoot *Tussilago farfara*, cow parsley *Anthriscus sylvestris*, Canada thistle *Cirsium arvense*, common sowthistle *Sonchus oleraceus*, etc. They form hardly approachable and thick overgrowth. More diverse varieties that are characteristic of natural meadows can be found in the channel K-12, e.g. the Early Marsh-orchid *Dactylorhiza incarnata* belongs to the category of protected varieties (Figure 4.1.6.1). Several specimen of this variety were found next to the bridge over the channel K-12. This variety is quite common in Lithuania and the most abundant in the family of *orchid plants*; it can adapt easily and grow and spread even in irrigation ditches.

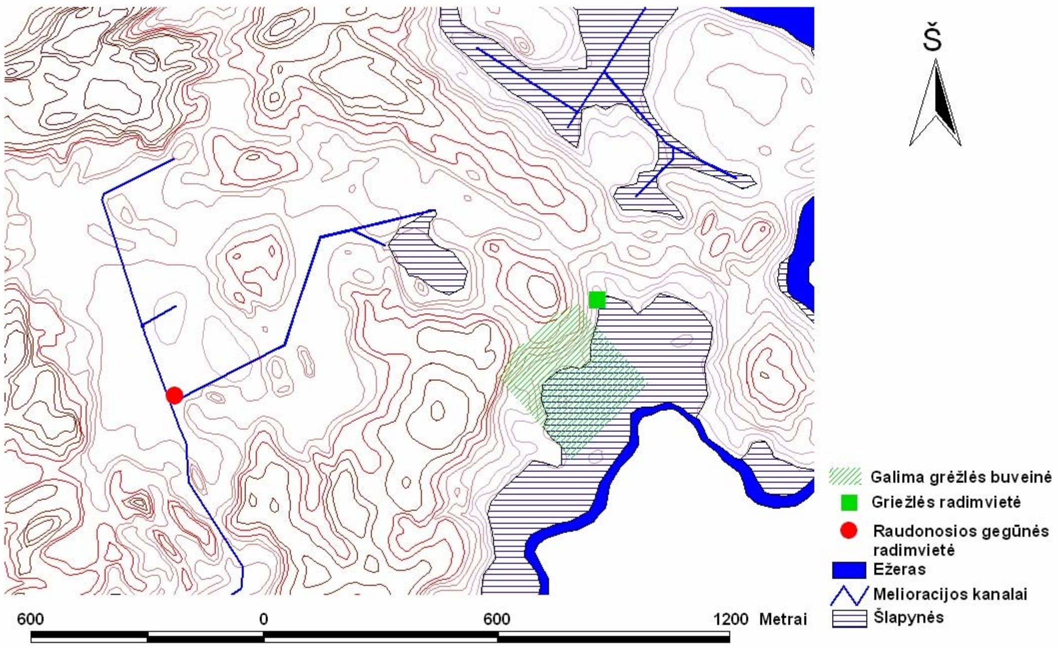


Figure 4.1.6.1. Finding places of varieties included in the Lithuanian Red Data Book next to Galilaukė site.

[Pav. vertimas:
Potential corncrake habitat
Corncrake finding place
Finding place of the Early Marsh-orchid
Lake
Irrigation channels
Wetlands]

No protected flora species have been found in the western part of the habitat yet. There is a lowland between the channels K- 8, K-10 and the sole field road, covered by particularly thick vegetation consisting of *cow parsley*, *Canada thistle*, *stinging nettle*, *piper betle*, *woolly burdock, etc.*

One species from protected species of birds was established – corncrake *Crex crex*. Corncrakes were spotted on the edge of the analysed habitat PV, towards the large loop of the Drūkša River and beyond the boundary of the habitat. There could be 2-3 couples of these birds in the whole habitat. Corncrake is the species that is included in the Lithuanian Red Data Book. However, this species is quite common because it spread and became more abundant due to the increased number of plots of abandoned soil and hayfields, and those are corncrake breeding grounds. Quail habitats *Coturnix coturnix* are likely to be found there as well. However, tall and thick vegetation reduces the suitability of pastures for this species everywhere – in highlands and lowlands. There are no conditions suitable for protected species of mammals, amphibians, reptiles and fish in this habitat.

APVARDAI SITE

The site of the potential repository is located in the agricultural land plot with a few field grove or tree groups of a very small size. The targeted hill and other highlands of the habitat are dominated by the following green crop of abandoned arable land and cultural meadows/pastures: *orchard grass*, *white sweet clover*, *scentless chamomile*, *tutsan,* etc. The relief slopes are covered by thick overgrowths of *cow parsley*, *piper betle*, *Canada thistle*, *and stinging nettle*, and by small *reed* plots in some places. There is a levelled land plot covered by the continuous overgrowth of *white sweet clover* in the south-eastern part of the habitat. In this place, efforts are made to plant a forest: birch and spruce seedlings were planted there.

The species composition of vegetation is analogous to that of Galilaukė in the entire habitat of the site – the same varieties are found there. The only difference is that there have not been found any species of protected plants there.

One protected bird species was established – *corncrake* (Figure 4.1.6.2). There could be 1-2 couples of them in this habitat. Another protected species – *quail* – is likely to be found there. However, the suitability of the biotypes for these birds is greatly reduced by tall and very thick grass vegetation. There are no conditions suitable for reproduction of mammals, amphibians, reptiles and fish in this habitat.

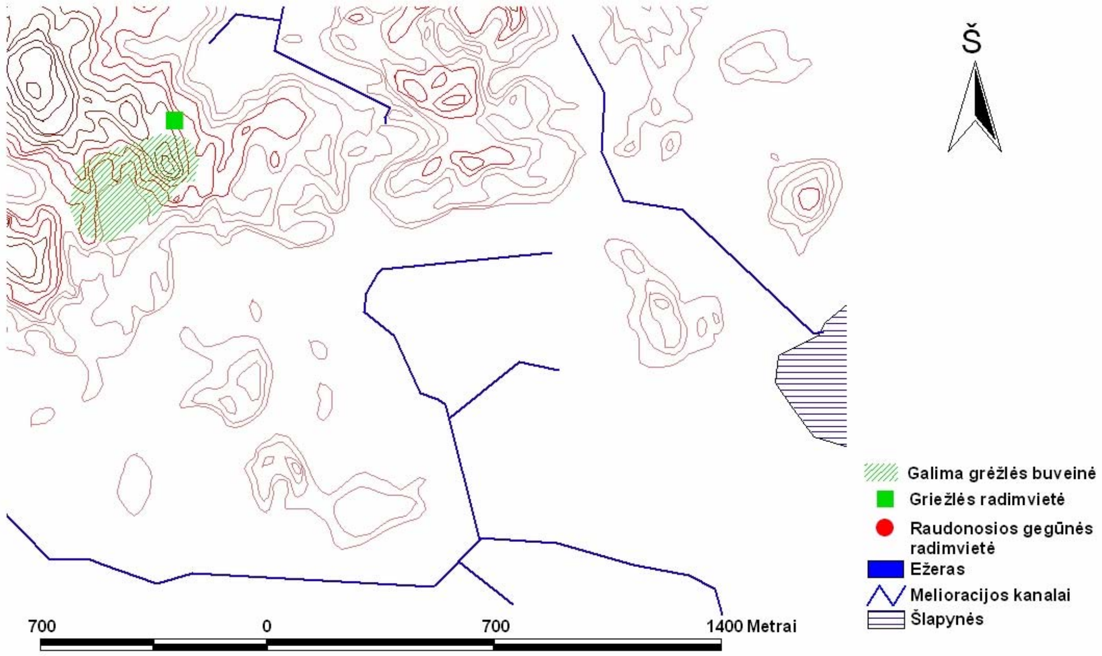


Figure 4.1.6.2. Finding places of varieties included in the Lithuanian Red Data Book on Apvardai site.
[Pav. vertimas:
Potential corncrake habitat
Corncrake finding place
Finding place of the Early Marsh-orchid
Lake
Irrigation channels
Wetlands]

STABATIŠKĖ SITE

The southern side of Lake Drūkšiai has been greatly affected by economic activities during the construction of the nuclear power plant or during its subsequent operation. The damage caused by building communication networks and roads was particularly great. The natural water outflow was disrupted and the water regime was damaged. As a result, water flooded small forests, waterlogged scrubs and seasonal or continuous lakelets were formed in some hollows. Another significant source of damage – the works carried out in a disorderly manner, during the performance of which the forest was polluted by construction waste.

The larger part of the former territory of Stabatiškė village is covered by forest and scrubs. The prevailing varieties include spruces, black alders, birches, asps, and pines. Efforts are made to afforest the glades of the forest (up to the construction of the power plant on arable land or in pastures and homestead places) – spruce seedlings are planted there. There are no protected plants there. Minor mammals – mousy rodents are common in the forest. Grey hares, roes, boars and mooses come to this territory as well. No rare and protected species of mammals and fish were found there. In addition, no rare and protected bird species were observed and no protected and rare plant varieties were found there either.

There are over 300 insect species found on the southern shore of Drūkšiai lake. There are very few insect species and no protected or rare species found in the planned Stabatiškė site. The detected background butterfly species of the agricultural landscape are trophically related to stinging nettles and cultural crucials. Those include peacock caterpillar (*Inachis io*), small tortoiseshell (*Aglais urticae*), large white (*Pieris brassicae*), small white (*Pieris rapae*), green-veined white (*Pieris napi*) butterflies, map butterfly (*Araschnia levana)*, beetles - *Pterostoma niger and Carabus hortensis*. Several dragonfly species are related to standing water bodies: *Sympetrum flaveolum* and *Aeshna cyanea*. The found insect species are common and abundant in the entire territory of Lithuania; no planned works pose any threat.

There are smooth newts (*Triturus vulgaris*), pool frogs (*Rana lessonae*), and a large population of moor frogs (*Rana arvalis*) and common frogs (*Rana temporaria*) as well as common toads (*Bufo bufo*) found in the aforementioned area; fire-bellied toads (*Bombina bombina*) were detected southwards from the planned site. Their finding place is shown in Figure 4.1.6.3. This is a protected species in the European Union (EU Habitats Directive, Annex II, Bern Convention – category II), which is included into the Red Data Books of Lithuania, Latvia, Sweden, Poland, and the Kaliningrad District (Russia). The spread of this European species in Lithuania is mosaic. It is a common species in Eastern, Southern and South-eastern Lithuania, whereas it is rarely found in other regions.

COMPARISON OF THE SITES

The specifics of biological diversity are analogous for the potential habitats of Galilaukė and Apvardai repositories. No valuable flora species the preservation of which would require special protection measures have been found there yet. So far a variety of flora – *Early Marsh-orchid* and a species of fauna – *corncrake,* which are included into the Lithuanian Red Data Book, have been found there. Both of these species are quite common in the whole territory of the Republic. The first variety grows remotely from the hill of the planned repository (its habitat would not be damaged during the construction) and the second species has suitable conditions to breed not only close to the particular hills but also in the areas around both habitats.

In terms of biological value, the sites are deemed analogous and do not require any special measures for the protection of biological diversity.

Figure 4.1.6.3. Finding place of fire-bellied toads.

4.1.7. Landscape

APVARDAI SITE

The surroundings of the sites are dominated by a landscape of insufficiently reclaimed, forested, lacustrine, hilly and tilled land. A relatively high level of natural features (due to swamps, lakes, and small forests) is typical of this land; however, it is also highly sensitive to technogenic impact (due to the dividing position and morphometric features of the relief).

The whole territory is anthropogenised: all the main elements of the landscape have changed due to long agricultural-economic activities, draining melioration, and technogenic restructuring of the surface (installation of a construction site and its subsequent recultivation). Even the most stable component of the landscape – the relief – underwent material changes: the waves of 6-9 m in height in the central part of the site were levelled and gravity drained hollows were formed in next to the hill. Closed interhill and interwave hollows became permeable. On the other hand, the degree of natural features of the landscape is particularly high due to the prevailing perennial grasslands (meadows and pastures) and forest plants: the ratio of relatively natural and technogenic areas in the contractual rectangle equals 340.

In terms of tree migration, the main hill is dominated by transeluvial facies (on the slopes), whereas interhill plots are dominated by transaccumulative and accumulative facies (in the interhill hollows). The ecotoneness of the territory is weakly expressed but it may increase in the future provided that the forest plants (spruces and birch stripes on the edges) remain in the levelled territory. Unfortunately, the current condition of forest plants suggests that there may be problems related to the transformation of ecological functions and agricultural purpose of the area in the immediate future: forest plants are not adapted to the features of the area, spruce seedlings are withering away (light green – the sign of extinction).

In geo-ecological respect, the most valuable element of the landscape is the small Kumpiai forest in the north of the main hill of the repository. The diversity of the landscape (and ecotones) of the site perimeter is greater. The southern (along Lake Apvardai) and eastern (along Gaidė stream) soggy places are especially significant. It is desirable that the construction of the object would not result in damage to their hydrological regime.

The aesthetic value of the landscape (observation spots) of the site itself is low. Within the perimeter of the site, there is a greater diversity of landscape, which increases the value of the landscape. The observation point on the Mikštas hill (the main hill of the repository) should be evaluated as medium or even lower; however, the high hills located next to it (closely next to it in northwest: Supakalnis, Klevas hill) are one of the most spectacular observation spots in the entire region. On the other hand, the values of these observation points will decrease only temporarily (about 20 years) as long as the repository is built and filled in.

In terms of resistance, the whole area of the site can be assessed as contrasting: as a hill that is slightly and medium sensitive to technogenic impact and a sensitive levelled territory. In terms of socio-ecological quality, the value of the territory is between low and medium.

GALILAUKĖ SITE

The surroundings of the sites are dominated by a landscape of insufficiently reclaimed, forested, lacustrine, hilly and tilled land. A relatively high level of natural features (due to swamps, lakes, and small forests) is typical of this land; however, it is also highly sensitive to technogenic impact (due to the dividing position and morphometric features of the relief).

The whole territory is anthropogenised: all the main elements of the landscape (hydrographic network, soil cover and its properties, vegetation and fauna; the features of mezzo and microforms were least affected; however, their changes are also considerable, for instance, formation of high slopes with deep deluvial soils performing the role of a particularly important geochemical barrier and basic outflow transformer) have changed due to long economic activities and draining melioration. Deep closed intercrest swamps turned into running water (transit) geosystems. On the other hand, the degree of natural features of the landscape is particularly high due to the prevailing perennial meadows and pastures: the ratio of relatively natural and technogenic areas in the contractual rectangle equals 60.

In terms of tree migration, the most common are transeluvial (on the slopes) and accumulative (in the interhill hollows) facies. The most important (in the geo-ecological respect) ectones according to the existing land use are cultural meadows/shrubby swamps (on the northern slope of the main hill). The ecological significance of this ectone is derogated by the fact that wide lifts containing ruderal nitrophylic vegetation are typical of the northern and north-eastern slope of Galilaukė hill, whereas the swamps are drained, covered by shrubs and do not have any typical ecologically significant spots.

In terms of landscape protection, it would be expedient to design and construct a repository in such a way that it would not cause any changes in the water regime of the natural wetland located northwards to the road Vosyliškės – Mačionys.

The diversity of the landscape (and ectones) in the vicinities of the site is considerably greater. In addition, renaturalisation (hollows soaking wet, spread of shrubs and wetland grass) can be observed in the vicinities as well.

The aesthetic value of the landscape (observation spots) of the site itself is contradictory. Within the perimeter of the site, there is a greater diversity of landscape, which, in conjunction with the archaic population system, significantly increases the landscape value. The observation spot on Galilaukė hill should be highly evaluated as there are almost all picturesque landscape elements in view, including those that are historically valuable (picturesque hills, forests, lake, river, old settlements, places of small estates with plants, remnants of the old roads and war fortifications, new technogenic dominants, etc.). On the other hand, after the repository has been filled and Galilaukė hill has regained its previous form, the value of the observation spot will not decline considerably.

In terms of resistance, the whole area of the site can be assessed as slightly sensitive to technogenic impact, whereas the main hill of the repository should be deemed medium sensitive. In terms of socio-ecological quality, the value of the territory is between low and medium.

STABATIŠKĖ SITE

Stabatiškė site comprises several concentrically situated hills surrounded by wetlands in the hollows. The relative height of hills above the surrounding hollows is 6-9 m. These hills can be clearly seen in the aerophotograph taken in 1952; Figure 4.1.7.1. The hills were arable, and there were pastures and a forest in lower places. There are 3-4 homestead places on the hills. The homesteads were abandoned before or during the construction of the INPP. During the construction of the power plant, a pig farm of the military division was established in the north-eastern part of the site. The surroundings of the farm and the part of the site located closer to the nuclear power plant is badly damaged – one can find construction waste there, and the sections of the ground are dug and used in the INPP for fixing the territory of the INPP.

The hollows located between the hills are wet and waterlogged. Dramatic changes were made during the construction of the Ignalina NPP. The agricultural irrigation system located in this area was damaged and a new drainage system was not installed. Road subgrades dammed up natural hollows. No attention was paid to the cleaning of the surrounding areas, including that of Stabatiškė. Due to the damaged drainage and inappropriate restructuring of the surface when building roads or engineering networks, water accumulates in the hollows seasonally or continuously. Water resulting from greater rainfall covers quite a large territory. Shrubs dominate the slopes and hollows of the hills. They are replaced by mature forest in some places.

Figure 4.1.7.1. Stabatiškė site in the aerophotograph taken in 1952.

Aesthetically, the most valuable component of the surrounding environment is a pond located in the north-western corner of the site. Another component is the old apple-tree garden which existed in the homesteads and survived the neighbourhood of the pig farm but was destroyed during the tests when implementing the INPP territory cleaning project. When implementing the aforementioned project, the glades on the top of the hills and homestead places were afforested – spruce seedlings were planted.

There are no other valuable landscape components (for example, observation spots) on the analysed site. The edges of the site are greatly affected by anthropogenic activities, whereas there is a fairly high degree of natural features in the central part of the site. The analysed territory will not gain any aesthetic value event after a forest has been planted there.

COMPARISON OF SITES AND LANDSCAPES

Similarities in landscape of the sites:

1. the areas are highly anthropogenised; however, the degree of relative natural features is very high due to the prevailing perennial grasslands,
2. there are certain foci of renaturalisation of the landscape,
3. in geo-ecological respect, the areas are stable but there are sensitive ectones and landscape elements (swamps) within their perimeter,
4. the socio-ecological quality of the sites is between low and medium.

Differences in landscape of Galilaukė and Apvardai sites:

1. Apvardai site is more damaged by technogenic processes,
2. Apvardai site is more sensitive to anthropogenic impacts.

There are no valuable landscape elements (for example, observation spots) in Stabatiškė site. The edges of the site are highly affected by anthropogenic activities, but there is a high degree of natural features in the central part. The installation of the repository will not impair the landscape but it might actually improve it.

4.1.8. Protected Areas, Ecological Networks and Immovable Cultural Values

This section of the report describes the position of a near-surface radioactive waste repository with respect to the natural carcass and protected areas as well as the position of the repository with respect to ecological networks and their elements. The location of the sites with respect to protected areas and ecological networks should be analysed on the basis of the following data:

- *Map of Lithuanian Protected Areas 1:400000, Department of Forest and Protected Areas under the Ministry of Environment, Register of Protected Areas, 1999;*
- *Localisation Scheme of the Natural Carcass of the Ignalina District. VU Landscape Management Group, 1993;*
- *Map of the Lithuanian Ecological Network (Eco Net). Lithuanian Fund for Nature, Institute of Geography, 2001;*
- *NATURA 2000 GIS Database (PROJECT: "Approximation of Lithuanian capacity, policies and procedures on Nature Protection to EU requirements, with particular focus on implementation of the EEC Habitats Directive (92/43) and the EEC Birds Directive (79/409)".*

The historical and archaeological values as well as other immovable cultural values related to the project and located in the construction area and in its vicinity are described as well. The protected areas of this part of the region are described in greater detail in other sources (*Kudaba. 1987; Ignalinos ... , 2002; Ignalinos AE ... , 1998; Identification ... , 2004*). The cultural heritage of the region is exhaustively described in the special publication of regional studies (*Gaidės ... , 1969*).

The distance to the closest protected areas of Latvia – the Silene Natural Park and Ilgai and Glushonka Nature Reserves is over 15 km; Figure 4.1.8.1.

4.1.8.1 Protected territory (Silene park) in Latvia (www.dap.gov.lv/public/files_uploaded/ izsardzibas_plani/silene_dap.pdf)

<u>APVARDAI SITE</u>

<u>*Location with respect to protected areas*</u>. There are no protected areas on the construction site and in its immediate surroundings. The nearest protected area is Pušnis Telmological Reserve, which is situated approx. 4-6 km southwards from the site. The areas of the Smalvas Landscape Reserve and Gražutė Regional Park lie northwest of the site, about 10 km away. The nearest protected area covers the protection zones and strips of Lake Apvardai. Under the "Rules for the Establishment of Protection Zones and Shore Protection Strips of Surface Water Bodies" (approved by Order No. 540 of 7 November 2001 of the Minister of Environment of the Republic of Lithuania), the width of the water protection zone of Lake Apvardai is 500 m from the shore.

<u>*Location with respect to ecological networks*</u>. In respect of the natural carcass, the site is also situated on the boundary: the north-western part of the site (the area that was formerly allotted to the NPP greenhouses) is not assigned to the areas of the natural carcass; the south-eastern part, which is situated closer to Lake Apvardai, is assigned to the internal stabilisation habitat area of regional significance.

The area has not been included into Lithuania's Eco Net. Only Lake Apvardai, which is located nearby, has been included into this network as a connecting element.

According to the preliminary *Natura 2000* network of the EU's protected nature areas, there are no areas assigned to this network neither within the territory of the site nor in its immediate surroundings.

<u>*Historical and Archaeological Values and Other Immovable Cultural Values on the Construction Site and in Its Immediate Surroundings*</u>. There are no data on the historical, cultural or archaeological values situated on Apvardai site. The nearest object to which attention should be paid is a closed cemetery in Vigutėnai village. It is noteworthy that the hill Kapelių Kalnas, in which bones have been detected while digging gravel since the old times, is situated at 0.5 km northwest of the main hill of the repository.

<u>**GALILAUKĖ SITE**</u>

<u>*Location with respect to protected areas*</u>. There are no protected areas on the construction site and in its immediate surroundings. The nearest protected areas are situated more than 10 km from the site: Pušnis Telmological Reserve (southwest of the site), Smalvas Landscape Reserve (to the west of the site), and Gražutė Regional Park (to the west of the site).

The nearest protected areas are the protection strips and zones of water bodies. The distance to open water bodies (Lake Drūkšiai and Drūkša river) is 0.5-1 km. Under the "Rules for the Establishment of Protection Zones and Shore Protection Strips of Surface Water Bodies" (approved by Order No. 540 of 7 November 2001 of the Minister of Environment of the Republic of Lithuania), the width of the water protection zone of Lake Apvardai is 500 m from the shore.

<u>*Location with respect to ecological networks*</u>. In respect of the natural carcass, the site is also situated on the boundary of the geo-ecological divide of regional significance (divided to the north and northeast of the site). The area to the south of the site (Varniškės and Švikščionys neighbourhoods) is not assigned to the areas of the natural carcass.

The area of the site has not been included into Lithuania's Eco Net. Only Lake Drūkšiai situated nearby is assigned to this network as the nucleus of national significance.

In accordance with the preliminary *Natura 2000* network of the EU's protected nature areas, Lake Drūkšiai and the Drūkša riverside bordering with the sites under consideration were singled out as habitats of protected bird species (the little crake, spotted crake, sea eagle, marsh harrier, and great bittern). The planned object would be situated at a sufficient distance from the Natura 2000 area (Lake Drūkšiai).

<u>*Historical and Archaeological Values and Other Immovable Cultural Values on the Construction Site and in Its Immediate Surroundings*</u>. There are no data on the historical,

cultural or archaeological values located on Galilaukė site. The nearest objects to which attention should be paid are as follows: a closed cemetery in Mačionys village and the German soldiers' graves dating back from 1914 in Švikščionys village. It is noteworthy that the formal descriptions of immovable cultural values situated in the vicinity do not precisely reflect reality. For example, there are the fortifications of the Hindenburg line (dating back to 1914-1917) which are not mentioned in the descriptions; and Russian soldiers from the both World Wars are buried in the so-called unattended German soldiers' cemetery (in the eastern part of the cemetery, towards Drūkša).

There was a thick network of Guriai manor estates situated in the area of the site and its immediate surroundings; however, the remaining elements of these estates (the building in Galilaukė village, a stand in Ščytnikai (the scientific base next to Lake Drūkšiai) do not have any exceptional historical value.

A highly valuable vicinity of the site (3.5 km to the north) is Pilies island in Lake Drūkšiai and the historical town of Drūkšiai (Drysviaty) known since the beginning of the XIth century.

STABATIŠKĖ SITE

Location with respect to protected areas. There are no protected areas on the construction site and in its immediate surroundings. The nearest protected areas are the protection strips and zones of water bodies. The distance to Lake Drūkšiai is about 2 km. The site is separated from the lake by the territory of the Ignalina NPP. More remotely situated objects are mentioned in the description of Galilaukė.

Location with respect to ecological networks. The area of the site has not been included into Lithuania's Eco Net. Only Lake Drūkšiai has been included into this network.

Historical and Archaeological Values and Other Immovable Cultural Values on the Construction Site and in Its Immediate Surroundings. When carrying out exploratory archaeological investigations on Stabatiškė site in June 2006, the place of the destroyed Stabatiškė estate (place of the village) was detected. A 0.5 m cultural layer with construction waste and several ceramic, metal and bone findings were detected in the central part of the estate area during the investigations. According to initial data, the area of the former estate place occupies approx. 1.95 ha (Figure 4.1.8.2). When carrying out additional exploratory archaeological investigations in the area of the Stabatiškė estate place (village place), the cultural layers of two periods (second half of the XVth century – XVIth century and second half of the XVIIIth century – XXth century), both of 20-80 cm thick, consisting of soil and clayey soil with construction and household ceramics, glass, osteological-archeological findings, were detected (*Dėl Stabatiškės..., 2006*). It was established that those are the remnants of the homestead which existed in the second half of the XVth century-XVIth century. People did not live there in the XVIIth century.

From the end of the XVIIIth century until the middle of the XIXth century, the Drūkšiai estate was passing from hand to hand and finally it was gradually sold out. At that time, the Stabatiškė location was repopulated as well (the village has been mentioned in the written sources since the end of the XVIIIth century). There was a small estate here. After the investigations have been carried out, the area of this object was revised (*Dėl Stabatiškės..., 2006*). The estate occupies an area of 1.5 ha (Figure 4.1.8.2).

There are alleged or unidentified monuments of immovable heritage in the area of the site. Mostly, those are natural hills called mounds by the local residents. No long-lived cultural layer has been found in them. There was the place of the Montvilai estate, which has not survived, next to the site. Other objects were destroyed or damaged during the construction of the NPP and its infrastructure, some of them (barrows) had been destroyed or damaged even before that. Their recreation or restoration should not be associated with the planned economic activities.

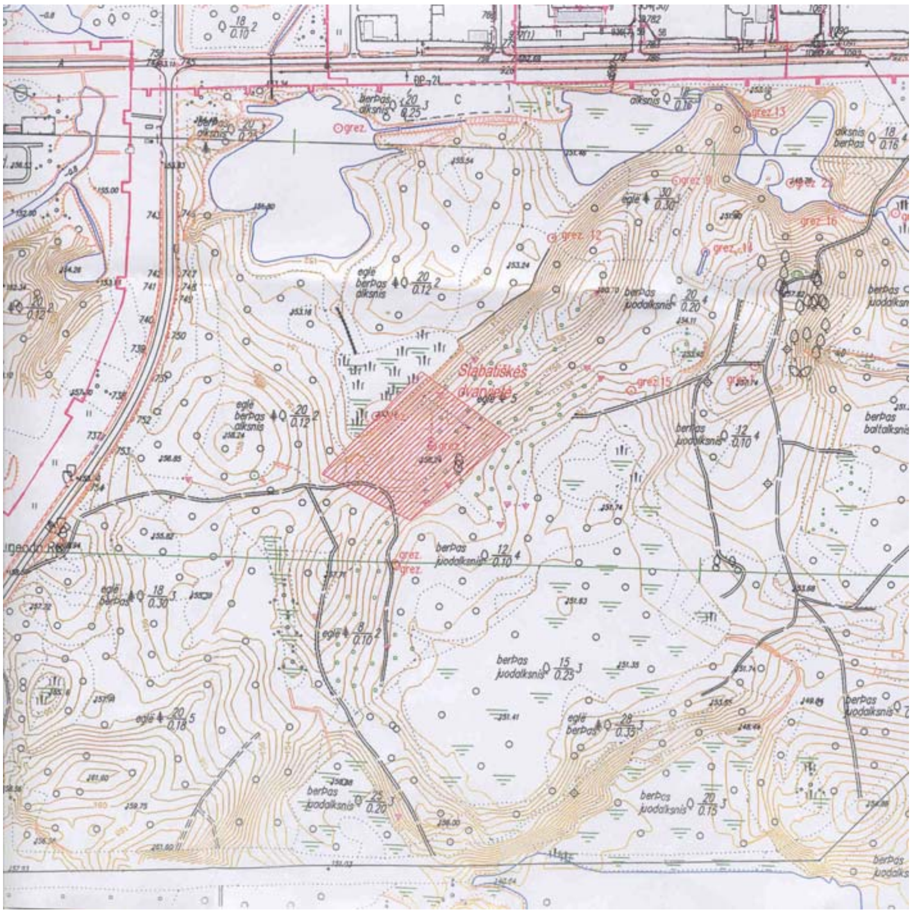


Figure 4.1.8.2. Area of the Stabatiškė estate.

4.1.9. Social-economic Environment

Some indices of the social-economic situation of the region can be provided only at the level of the habitat or region and Rimšė subdistrict. Other indices, which are more closely related to the location and features of the area, are discussed for each site separately.

Social-Economic Significance of the Region

Particularly deep contrasts have been formed in social development of the population in the area under consideration *(Atominė ..., 1997; Ignalinos AE regiono ilgalaikio ... , 1998; Socialiniai ... , 1999; Ignalinos AE regiono ... , 2002; Identification ... , 2004; Ignalinos atominės elektrinės regiono ... , 2004)*. The region of the Ignalina NPP can be described as the region of a deep long-term demographic crisis and of the lowest income of residents in the country (excluding Visaginas and the INPP) and at the same time as the focus of the most favourable demographic processes and of the highest income level (Visaginas and the INPP). The maintenance of the region of such a contrasting stability and implementation of sustainable development can have an impact on the social stability of the whole North-eastern Lithuania and perhaps even on that of the entire country. It is noteworthy that the region is particularly significant in terms of multi-cultural development as the habitat of juncture and interaction of different cultures. Another important fact is that the region is distinguished for its unique consistent political orientation (it is defined as a separate political geographical region) and is exclusively important for the country's political stability (with regard to both the domestic and international contexts).

The economic significance of the region is deemed to be contrasting due to the hardly co-ordinated directions of economic development which were formed during the Soviet times. On the one hand, the region is distinguished for its particularly high energy potential of national (and transnational) significance. On the other hand, the significance of the region's industry and traditional bioproduction sector (except for the forestry sector) to the country's economy is rather poor (the region supplies only 0.5% of the country's industrial production, 1-2% of agricultural produce and attracts only 1.4% of material investments). Third, the region has an exclusively high potential of tourism and recreational resources and has been and currently is one of the most important regions in Lithuania's recreational industry, which had and is recovering its international significance.

According to the *Master Plan of the Republic of Lithuania* approved in 2002 *(Lietuvos Respublikos ..., 2002)*, the priority prospective functions in the region are sustainable forestry, recreation, and conservation. This region is the second (after the seashore) functional area with the distinguished recreational use priority of national significance. On the other hand, the *Master Plan* recognises that the local habitats of industrial development (within the area of the Ignalina NPP) are foreseen in the region.

The purpose of the agrarian areas of the region is arable farming of low and medium intensity in plots that are sensitive to erosion. In terms of resources, priority is given to grassland development and activities alternative to agriculture. The region has favourable conditions for forest development in degrading or abandoned arable areas. In addition, there are favourable conditions for the development of hunting, fishery and beekeeping. In a long-term perspective, the forestry sector of the region should be oriented towards a more intensive recreational use of forest and protective functions of forests.

Peculiarities of Population and the Social and Cultural Structure

In terms of population territorial system, the sites under consideration are located in scarcely populated areas, in the habitat of particularly small and densely situated rural settlements.

The birth-death ratio in 2002 was 1:8; however, a significantly higher number of people come to live in Rimšė subdistrict than that of people leaving it; therefore, the number of population is relatively steady. Compared to other subdistricts, the migrability of residents is high in Rimšė subdistrict. There are only 13.7% of children under 15 years of age – this is the worst index among the subdistricts in the Ignalina district. The social-economic situation should be assessed as contradictory: the villages are dominated by very small farms (61% - <5ha); however, due to the proximity of Visaginas Rimšė is gradually turning into a suburban settlement. The unemployment level is high in this subdistrict and stands at 37%.

The typical feature of the current population system of this region is that the number of non-local only registered residents who usually do not permanently reside in Rimšė subdistrict is increasing. They are becoming a significant social and political factor because they have all the rights to voice their opinions as community members. It has been observed that the number of "residents" who have electoral rights is approximately the same as that of permanent residents. The main factors of such geodemographic development are as follows: the border zone (previously the most important factor because Belarusian visas were cheaper and the crossing of the border was simpler due to the registration in the border zone) and the proximity of Visaginas.

It should be noted that the region is particularly significant in terms of multi-cultural development as the habitat of junction and interaction of different cultures. Rimšė subdistrict is distinguished for its varied national composition, and Lithuanians are a minority there.

Settlements of the Republic of Belarus

Several major (Drūkšiai, Gireishi, Grituny) and some 15 small rural settlements are situated on the Belarusian side at a distance of up to 5 km from the border with Lithuania. The town of Drūkšiai (a local centre of services, agricultural production and border protection) has a population of about 300. The settlements of Gireishi and Grituny are situated on either bank of the old river-bed of the Drūkša, some 7 km southeast from Drūkšiai. Grituny lies further north and has a population of less than 100 (it is believed that there are about 15 homesteads left). Gireishi further to the south used to be the centre of a soviet farm and grew at that time: even apartment houses were built there. After the Gireishi soviet farm was merged with the Drūkšiai soviet farm, the growth of the settlement stopped. Gireishi has a population of approximately 250. Barkovshchizna settlement is situated closest to the planned facility, next to Galilaukė (4-5 residents; it was a major settlement until 1940, the estate place, and a local centre). The Lithuanian side in the area between Lakes Apvardai and Drūkšiai is not connected by roads with the abovementioned settlements. The total population of the 5-km-wide borderland on the Belarusian side is 600-800. This number is gradually decreasing.

The town of Vidžiai (Vidzy, a population of some 2.2 thousand) and Breslauja (Braslav, the region's centre with a relatively stable population of approx. 9.5 thousand) are local and regional centres in the area.

Information about Health Conditions of Residents

There are no reliable data on health conditions of the local residents. The reason for this is the peculiarities of the territorial organisation of public health care and medical statistics.

Under the procedure for the organisation of primary health care, part of the residents of Rimšė subdistrict are registered in Ignalina, some in Dūkštas, and the remaining part is registered in Visaginas primary health care institutions. There are no records on health conditions of residents according to individual territorial units. Ignalina Branch of the Utena County Public Health Centre keeps only the records of infectious diseases on the basis of the territorial principle. In this respect, the described area is not exceptional. The last cases of smallpox were registered in the examined habitat in 1910, whereas the last cases of typhus fever in 1941-1945.

There is the so-called paramedic's station in the centre of the subdistrict, in Rimšė. According to the medical specialist working there, the health of the local residents is good having regard of their age and lifestyle, no anomalies and pathologies have been observed.

It is noteworthy that health conditions of the local residents were examined and evaluated as contradictory when implementing the national scientific programme "Nuclear Power and the Environment" *(Atominė ... ,1997)*. In 2000, the Kaunas Medical University carried out tests on thyroid gland changes in the region of the Ignalina NPP. According to informal data, it was established that the changes in thyroid gland of pupils of the then Rimšė secondary school were anomalous. This information cannot be directly related to the environmental impact of the planned economic activities and should be considered only as its context, especially having in mind that there are no school age children living permanently in the area of Galilaukė and Apvardai sites.

According to primary health care specialists, there are no pre-conditions to believe that the health situation of the residents of Rimšė neighbourhoods can significantly differ from the average of the Ignalina district because the demographic composition of rural residents and their lifestyle are similar in the whole district (this conclusion was made in the previous examinations of the local residents' health as well).

Morbidity of malignant tumours in the Ignalina district is lower than the average in Lithuania and in the Utena district. The statistical indicator of resident visits to primary health care institutions (on average, 4.1 times per year) is one of the smallest in Lithuania; however, it should actually be higher because part of the local residents uses the services of the Visaginas policlinic. On the other hand, this indicator is typical of rural districts. It should be observed that the districts of Ignalina and Zarasai are distinguished for a high number of persons who receive emergency medical aid. There are no data to confirm whether this is typical of the described habitat (Rimšė neighbourhoods) as well. The trends and morbidity of the so-called social diseases in the Ignalina district are similar to those in other rural districts. The disability of the local residents is mainly caused by circulatory system diseases (20-30%). On average, the number of people with mental and behavioural disabilities is higher in the Ignalina district that in the county.

Information about Natural Resources and Land Prices

Significance of land resources. The region has peat and loam resources that are significant on a national scale. In 2004, the Ministry of Agriculture of the Republic of Lithuania assigned the entire Ignalina district (Dėl mažiau …, 2004) to areas less favourable for farming: there is a high percentage of low productivity land (30.9%), poor productivity of cereals (1.50 t/ha), and low density of rural residents (10.2 residents/km^2); however, there is a relatively high number of able-bodied population employed in the bioproduction sector (29.5%). The number of population is rapidly decreasing (1.5% per year). For this reason, a threat arises for such areas to be abandoned.

Land prices in the region should be discussed as an economic factor and condition separately. Land base prices in the region are as follows (Table 4.1.9.2):

Table 4.1.9.2. Land base prices in the habitat of Galilaukė and Apvardai sites.

Purpose of land	**Price, LTL/ha**	**Comments**
Commercial	10,600	None on the sites and in the

		vicinities
Household	7,800	None on Apvardai site
Industrial, warehousing	6,100	None on the sites and in the vicinities
Partnership of gardeners	8,300	None on the sites and in the vicinities
Agricultural	604	

Under these circumstances, the most important is the price for agricultural land. It was established that the price for agricultural land in Rimšė subdistrict (except the town) varies from 200 to 2m000 LTL/ha depending on cultivation.

On the Belarusian side, there are no significant natural resources on a national or regional scale either. The bioproduction sector is of low productivity. The specialisation of the region is production of foodstuffs and flax processing (there are milk processing, brewing and fish companies as well as a flax factory in Braslav).

Nutrition Peculiarities

For the purpose of forecasting exposure doses, it is important to know the food sources and nutritional habits of the local residents; however, there are no detailed data on the sites.

According to the most recent data, the traditional nutritional structure and habits of the local residents were mostly influenced by a relatively good access to the town and its supermarkets as well as demographic and family structure changes in the habitat. The nutrition of the local residents is dominated by imported products. The main products used of local origin include milk, potatoes, and vegetables (cabbages, beetroots, cucumbers). Taking due account of land use, the composition of the local residents and their nutritional habits, the most important are milk products and potatoes.

According to the data of the survey carried out among the local residents (in 3 settlements in August 2004), one family household, on average, has 1 cow producing approx. 3,000 kg of milk per year, produces approx. 300 kg of pork and about 0.6 t of potatoes for food (for forage – a very variable quantity, depending on the number of animals kept) and about 0.1 t of other vegetables (mainly, cabbage).

Almost all unprocessed milk and 2/3 of potatoes, 2/3 of vegetables, and approx. 1/3 of meat are used for food or as forage for pigs. According to the local residents, they consume from 1 l of milk per week to 1 l of milk per day. Sour cream consumption is from 1 l per month to 1 l per week. Almost all bread, flour and grits products (with rare exceptions) are purchased externally. The average consumption of bread, flour and grits products is 1.5 kg per week per capita. Also, sugar beets and triticale are grown for forage. The yield of the latter – 1.0-1.2 t/ha.

The nutrition peculiarities of the local residents are influenced by their old age as well. Therefore, their nutrition can significantly differ from the average nutrition of a Lithuanian resident (Table 4.1.9.3).

Table 4.1.9.3. Average foodstuff consumption in Lithuania, kg per year (Kadziauskienė ir kt., 1997)

Product	**Males**	**Females**
Vegetables (excluding potatoes)	77	61
Fruits	50	74
Cereals	66	42

Milk and milk products	119	114
Meat and meat products	73	43
Fish and fish products	8	6
Fat	15	8
Potatoes	107	70

Information about Crops

This information comprises the crop structure, areas and yield. It is noteworthy that there is a lack of information about the structure of agricultural land and crops, and the structure of agricultural land and crops at different territorial levels – micro-local, local and regional – greatly varies; therefore, data of higher level units can be applied to lower level units only upon agreed limitations. Statistical, declared and actual data differ significantly, and the crop structure changes relatively quickly.

In the lowest territorial units – in the immediate surroundings of the sites, crops occupy a very small portion of area – up to 2%. On Galilaukė site, in the immediate surroundings of the repository, there is on average within 0.5 km radius only about 0.8 ha of potatoes, 0.8 ha of cereal crops, 0.2 ha of vegetable crops, and about 1 ha of gardens. In the surroundings of Apvardai site, the quantity and structure of crops depends on the layout of the repository in the location. According to the version analysed in this study, there are no crops in the immediate surroundings of the repository. For the description of a wider habitat, the data on the crop structure of Rimšė subdistrict would be suitable; however, there are no such data available. Even after the crop declaration system has been designed, under the current procedure, neither the subdistrict council, nor the agricultural department of the district do not have initial data. These data are stored and processed by the National Paying Agency, which cannot provide the required initial information at the subdistrict level. Having compared the land factors of several typical habitats, it may be concluded that crops occupy not more than 15% of the subdistrict's agricultural land (total agricultural land comprises approx. 6,800 ha). 20% of crops are potatoes, and about 65% of crops are feeding crop, whereas the remaining portion consists of field vegetables and other. It should be noted that there are many gardens in the area of the subdistrict (the total area, including industrial land, is >200 ha).

The crop structure of the Ignalina district is not very suitable for the interpretation of average conditions (irrespective of the formal inclusion of both sites into the area of the Ignalina district) because the district averages are distorted by the relatively fertile Dysna plain, which is different by its crop structure and in particular by their productivity. Therefore, it would be more expedient to use average data of the Ignalina NPP region (Ignalina and Zarasai municipalities) for calculations of average conditions. Table 4.1.9.4 contains the crop structure of the region, whereas Table 4.1.9.5 shows the average productivity of the main cultures in 1998-2002. The data of the 2003 Census of Agriculture can be used as well; however, one should pay attention to the fact that the conceptions of crops in the previous statistics and in the Census of Agriculture differ significantly (Table 4.1.9.6).

Table 4.1.9.4. Average crop structure in the Ignalina NPP region in 1998-2002.

Crops	Area, thous. ha	%
Cereals	11.3	81
Flax	0	0
Sugar beets	0	0
Potatoes	2.3	16
Field vegetables	0.4	3

Total	14.0	100

Table 4.1.9.5. Average productivity of some cultures in the Ignalina NPP region in 1998-2002.

Crops	**Productivity, t/ha**
Cereals	1.4
Potatoes	9.9
Field vegetables	

Table 4.1.9.6. Crop structure in the Ignalina NPP region according to the 2003 Census of Agriculture

Crops	**Area, thous. ha**	**%**
Cereals	6.9	51
Legume crops	0.1	0
Industrial crops	0.0	0
Potatoes	2.3	17
Field vegetables	0.3	2
Feeding crops	4.0	30
Total	13.6	100

It is important to consider foodstuff flows from the habitat as well. The prevailing semi-organic farm does not form constant significant flows of agricultural produce from the habitat. After the territorial milk raw material purchase system has been restructured, the purchase of milk has stopped (except for the closest neighbourhoods of Rimšė). A small share of milk and milk products is supplied to the residents of Visaginas. Sometimes beef cattle and small quantities of potatoes, vegetables, apples and fish are supplied to the market from the habitat. The consumers of the majority of the products supplied to the market are the residents of Visaginas; however, beef cattle are supplied to meat processing companies operating in the Vilnius district and Utena. Horses purchased for meat in the habitat used to be exported to Italy (Sardinia). Due to a small number of farms and the organic nature of these farms, only a very small portion of agricultural produce from Galilaukė and Apvardai sites are consumed beyond the boundaries of the described areas. There are no significant berry, mushroom and herb resources on the sites and in their immediate surroundings; therefore, they are not supplied to the market.

No data have been received on the crop structure and productivity in the neighbouring territory of Belarus. The summarised data of Vitebsk district are not suitable because the crop structure can considerably differ due to geographical differences. When comparing the land factor structure of neighbouring border areas of Lithuania and Belarus and taking into consideration the similarity of natural features and the degree of cultivation, it is likely that there should be no material differences in the crop structure. They might be slightly increased by different forms of farming. According to informal data, there are bigger areas of flax and cereal cultures in the region of Braslav; besides, they started to grow rapes.

Information about Fish Catch

No systematic commercial fishing is carried out in Lake Drūkšiai. Although there is a formal possibility of commercial fishing, only 0.4-1.0 t of fish (i.e. 0.3 kg/ha of fish) is caught there episodically according to the market needs. The extent of non-commercial fishing is several times larger, sufficient to fill the local market. It is noteworthy that the local market is more oriented to the consumption of sea fish due to the peculiarities of the geocultural composition of residents of Visaginas.

Average data of Lithuanian lakes can be applied to other lakes in the habitat. It should be noted that fishery organisations and specialists state that we do not have any reliable statistics on fishing in internal waters. They propose to rely on the average data of the 9th decade of the XXth century. Until 1990, the average fish catch in lakes amounted to 11 kg/ha of fish, i.e. 33% - roaches, 18% - breams, 12% - perches, and 10% - pikes. The extents of commercial and amateur fishing in lakes were almost the same. After 1990, the fish catch in internal water (including lakes) decreased approx. 3 times. The forecast is that the fish catch in internal waters will reach 50% of the 1990 level in 2015.

The abundance of fish and fish composition in Lake Drūkšiai are determined by its thermal change. After the Ignalina NPP had been put into operation, the cold-water fish community of a vendace-smelt type started to turn into a warm-water fish community of a roach-bream type. During the recent years, the situation of the fish population has been stabilised, and the biomass is increasing. After the termination of the NPP operations, a reverse process may take place. The potential maximum catch can amount up to 30% of fish biomass.

Industrial or Military Activities in the Surroundings of the Sites and Other Factors that may have an Impact on the Safety of the Facilities

There are no dangerous industrial objects, except for the Ignalina NPP itself, in the surroundings of the sites. There are no high-pressure pipelines in the surroundings of the sites. The gas pipeline Pabradė-Visaginas being designed will be laid to the west of Apvardai site; however, it will not be (preliminary) in its immediate surroundings (to the west of Rimšė).

There are high-voltage electricity transmission lines next to Apvardai site (from the north); however, they are not related to the safety of the facility.

The location of the sites with regard to air transport routes is favourable because there are no constant air corridors above them. The sites are included into the flight prohibition zone above the INPP (within a 5.4 nautical mile radius). There are no other flight prohibition zones in the surroundings of the sites. No dangerous (in terms of air accidents) zones have been singled out in the surroundings of the sites. The nearest operating military aerodrome is 50 km away, in Belarus, by Pastovimis, the non-operating one is in Latvia, close to Daugpils (35 km). The nearest registered civil aerodrome in Lithuania is in Zarasai (28 km; almost unused).

APVARDAI SITE

The social significance of this area is low due to a small number of population and its demographic situation. The economic significance of the area is not very high either because it is used for extensive agriculture of organic nature and propagation of forest cultures after recultivation. In a long-term perspective, forest development will also have only local significance in terms of resources. The recreational significance of the area is very small due to a lack of conditions and resources. There are no other significant natural resources in the area. In a perspective, the agrarian significance of the area may increase because it (and its vicinities) is dominated by major arrays of cultural meadows and pastures favourable to development of ecological stockbreeding in big-scale farms.

There are no residents and homesteads on Apvardai site. In its vicinities (within its perimeter), there are several settlements (Table 4.1.9.7). The average number of population is 22. The number of population is decreasing in this area, and the dominating social group of residents are old-age pensioners.

Table 4.1.9.7. Settlements and population on Apvardai site and in its vicinities (2001).

Settlement	Total formal number of population	Males	Females
Žibakiai	33	13	20
Girdžiūnai	7	3	4
Bieniūnai	57	30	27
Tripuckai	9	4	5
Vigutėnai	6	2	4
TOTAL	112	52	60

There are no data about differences between the formal and actual number of population; however, it is known that the users of the land plots situated in the vicinities of the site area reside not only in neighbouring villages but in other locations as well (Visaginas, Gaidė, Rimšė).

Over the past 40 years, the region has been experiencing a significant depopulation. According to the data of the population censuses, the number of local population continues to decrease rapidly. Compared to 1959, the number of population has decreased by 3.1 times (Table 4.1.9.8).

It can be presupposed that no permanent residents should remain almost in all the settlements within the nearest 20 years. If the current trends continue, there are no preconditions for improvement in the demographic situation. The prevailing social group is old-age pensioners.

In terms of economic development, the proximity of the Guriai estate and the town of Rimšė as well as a good connection (by highway and narrow gauge railway) to the local and regional centres had an impact on the location of Apvardai site. For this reason, this area was reclaimed more intensively in the past. The area consisted mainly of the territories of Girdžiūnai and Tripuckai villages.

Table 4.1.9.8. Change in the number of population in 1959-2001.

Settlements	1959	1970	1979	1989	2001	Change coefficient*
Bieniūnai	64	82	89	63	57	-1.1
Girdžiūnai	51	36	22	15	7	-7.3
Tripuckai	81	39	29	21	9	-9.0
Vigutėnai	40	33	19	11	6	-6.7
Žibakiai	112	73	59	48	33	-3.4
TOTAL	348	263	218	158	112	-3.1

* The symbol + shows how many times the number of population has increased, and – how many times it has decreased, compared to 1959.

During the Soviet times, the main factor of economic development was the rapidly developing Apvardai collective farm (the centre was in Bieniūnai). At that time, multi-branch stockbreeding (milk and meat cattle breeding, pig breeding, aviculture) was developed. After a large array between Žibakiai, Tripuckai and Bieniūnai had been drained and irrigated (the projects were prepared around 1966 and implemented around 1972), the big-scale meadows and pastures with cattle paths and water-supply were equipped. Cultural meadows were undersowed; a dam was built by Lake Apvardai. In the 8th decade of the XXth century, after the local residents had been removed, a plot was prepared for the construction of the NPP greenhouse factory in the south-eastern part of the site: the arable layer was dug off, and the surface was levelled (in the area of approx. 25 ha). Land was transferred to the INPP. When the construction had been stopped after the Chernobyl accident, fertile soil was taken to allotment gardens in Visaginas and neighbouring homesteads and also used for territory cleaning works in the town of Visaginas. The water-supply system from Lake Apvardai being constructed was abandoned. The area has not been used for over 2 decades. In 2003, following the long-term demands of the Ignalina Municipality, the NPP management organised a tender for land recultivation, as a result of which, the area was reploughed, the system of drainage ditches was reconstructed, access roads were laid, and the spruce culture was planted (with birch stripes on the edges). It should be considered that the perspective of forest in this area is hardly likely: land is not very suitable for this, and besides, the seedlings are thickly covered by sweet clover. During the first years, the spruce seedlings turned yellow.

The structure and nature of the current local economy: organic agriculture is the prevailing sector with milk and meat cattle breeding as the dominating branch. The local economy has no marketable significance but in a perspective it could have due to conditions that are relatively favourable for development of ecological farming. The vicinities of the area are used for recreational purposes as well (mainly by the local residents who moved to Visaginas). There are no significant investments in the area and its vicinities; however, investments are made into the restructuring and development of homesteads. According to the local residents, the main factor that is favourable for economic development is good access, and the main obstacle is a lack of waters suitable for recreation. On the real estate market, supply exceeds demand (due to the lack of water bodies): there is no land market, only the trade in homesteads (even without access) situated by the lake is being carried out. It is believed that the area of beautiful scenery situated in a good geographical location, next to the town of Rimšė, which is turning into a recreational settlement, cannot be considered as prospectless even if it lacks waters suitable for recreation.

Local natural resources are currently used only for the local bioproduction sector and limited recreation.

State-owned land dominates the whole area of the site; however, there are several (3-10, depending on the boundaries of the site) private land plots. Within the perimeter, there are small-scale land plots: there are 25 of them; also, there are reserve land plots as well. Kumpiai forest was privatised as well. There were 9 land plots in the levelled area prepared for greenhouses but their ownership was transferred or compensated.

The average land estimation is very different (the value of concrete land plots is currently being specified). The market price of land (if there is any market) could be slightly higher than the base price.

GALILAUKĖ SITE

The social significance of this area is particularly low due to a small number of population and its demographic situation. The economic significance of the area is not very high either because it is used for extensive agriculture of organic nature. The recreational significance of the area is very small due to a lack of conditions and resources (however, the vicinities are favourable to local-scale recreational activities). There are no other significant natural resources in the area. On the other side, this marginal border area has significance in terms of border protection and national defence; therefore, it cannot be abandoned and not developed further even if it does not have a significant social-economic potential.

On Galilaukė site, there is 1 homestead (formally, Galilaukė settlement which is sometimes assigned to Vosyliškės) and several settlements (Table 4.1.9.9) in its vicinities (within the perimeter). Galilaukė and Kalnežeris are considered to be steadings, whereas other settlements are considered to be villages. The average number of population in the settlements is merely 8.

Table 4.1.9.9. Settlements and population on Galilaukė site and in its vicinities (2001)

Settlement	Total formal number of population	Males	Females
Galilaukė	6	3	3
Kalnežeris	4	2	2
Mačionys	3	1	2
Švikščionys	16	5	11
Varniškiai	11	5	6
Vosyliškės	9	5	4
TOTAL	49	21	28

There is a significant difference between the formal (registered) and the actual number of population. The actual number of permanent residents in the settlements of Galilaukė, Kalnežeris, and Švikščionys is lower than the formal one.

Over the past 40 years, the region has experienced a significant depopulation. According to population censuses, the number of local residents continues to decrease rapidly. Compared to 1959, the number of population has decreased by 2.7 times (Table 4.1.9.10).

Table 4.1.9.10. Change in the number of population in 1959-2001.

Settlements	1959	1970	1979	1989	2001	Change coefficient*
Galilaukė	6	5	7	6	6	No changes
Kalnežeris	4	4	4	3	4	No changes
Mačionys	19	11	6	5	3	-6.3
Švikščionys	43	32	28	20	16	-2.7
Varniškiai	53	29	30	19	11	-4.8
Vosyliškės	7	25	28	7	9	+0.8
TOTAL	132	106	103	60	49	-2.7

* The symbol + shows how many times the number of population has increased, and – how many times it has decreased, compared to 1959.

It can be presupposed that no permanent residents should remain almost in all the settlements within the nearest 20 years. If the current trends continue, there are no preconditions for improvement in the demographic situation. The prevailing social group is old-age pensioners.

In terms of economic development, Galilaukė has always been deemed as a back-country (except for the prosperity of fishing business before the World War I). Small-scale estate agriculture was prevailing. The location suffered a particularly sharp recession as a result of the prolonged positional war during 1914-1917: the region was totally wasted. The residents started to leave their underground hideouts only around 1930. During the World War II (in 1944), the front has stopped there for a long time as well. During the Soviet times, due to its remoteness and distance from roads the reclamation and modernisation of the region took place later and on a slower pace than anywhere else in Lithuania. During the eighth decade, after the interhill swamps had been drained, several large-scale plots of arable land were formed between Galilaukė, Varniškės and Švikščionys. Wheat, rye and barley were cultivated there but yields were small. The land was limed (from planes; the agrochemical aviation site was on the top of the Galilaukė hill). In

Vosyliškės, there were farms and a brickyard of the collective farm. Arable land was desolated around 1994-1995. It was used as meadows and pastures for local needs. The state of grasslands is satisfactory (except for burnt peatbogs which are covered by shrubs), drainage is relatively effective (except for spring periods).

The structure and nature of the current local economy: organic agriculture is the prevailing sector with cattle breeding as the dominating branch. Horses are also bred. There are gardens as well. The economy has no marketable significance. The area (particularly in the vicinities) is used for recreation as well (mainly by the local residents who moved to Visaginas). There are no significant investments in the area and its vicinities, except for the repairs of several homesteads in the villages of Mačionys, Varniškės and Švikščionys. Despite sparse population, remoteness, border regime and other unfavourable circumstances, the number of desolated homesteads is relatively low. On the real estate market, supply exceeds demand (due to the lack of water bodies and limited accessibility). Local natural resources are used only for the local bioproduction sector and limited recreation. The main obstacle in the development of this type of economy is a lack of water bodies and water resources in general (in Galilaukė) as well as the border regime (in Švikščionys and Mačionys).

State-owned land dominates the entire area of the site (except for 1.4 ha in Galilaukė) but the private use of land prevails. Within the perimeter of the site, there are 7 small private land plots.

The average estimation of homestead land is about 40 points and that of other land plots is 30-35 points. The value of land is still being specified (for particular land plots) but preliminary it is higher than the aforementioned average (due to irrigation). There are no land servitudes on the Galilaukė land plot.

STABATIŠKĖ SITE

There are no residents on Stabatiškė site and in its surroundings. They were evicted before the construction of the nuclear power plant.

Taking due account of the changes that have taken place, it should be stated that, after the construction of the power plant had been completed, a large number of damaged (the fertile soil layer was destroyed and the relief was transformed as a result of digging and construction), desolated and unused plots appeared (VĮ Ignalinos..., 1999). When drafting the detailed plan, Stabatiškė hills were allotted to the group of desolated and slightly or medium damaged land. The majority of them are desolated agrarian land and places of homesteads, where soft deciduous trees and shrubs are being restored.

When the boundaries of the state enterprise Ignalina Nuclear Power Plant were changes, the plots situated within the 3 km sanitary protection zone of the nuclear power plant were left for this enterprise (VĮ Ignalinos ..., 1999). This zone also includes the area of Stabatiškė, which has been assigned the forest purpose. This area was granted the status of protective forest of group III. Group III of forest comprise protective forests. Those are forests in geological, geomorphologic, hydrographic and cultural reserves, in reserves of this kind situated in state-owned parks and in areas of biosphere monitoring, and in protection zones, as well as other forests (Forestry Law, Official Gazette *Valstybės Žinios*, 1994, No. 96-1872). The aim of farming in the aforementioned forests is to form productive stands capable of performing the function of soil, air, water, and human living environment protection. Non-smooth and small (up to 5 ha) and smooth development and sanitary cuttings are allowed.

Article 11 of the Forestry Law provides that forest land may be turned into land for other purposes only in exceptional cases, by combining the interests of the state, the forest owner and the general public under the procedure established by the Government. It is prohibited to turn forest land into land for other purposes in reserve forests falling into Group III and in other forests situated in the protection zones of shores of surface water bodies and sub-zones of physical protection of heritage objects. Forest land which is not afforested yet (forest fields, dead stands, cutting places) is turned into land for other purposes first as well as in such cases if there are deciduous stands damaged by natural disasters or that have become thin otherwise (Procedure for Turning Forest Land into Land for Other Purposes, Official Gazette *Valstybės Žinios*, 14 05 2002, No. 48-1840). In all cases, due account has to be taken of the significance of forests for environmental protection. In forests falling into group III, which are not in the aforementioned protected areas, forest land may be turned into land used for other purposes even if no master or special planning documents – forest management project plans of the municipal area or parts thereof have been prepared and approved under the procedure established in the Law on Territory Planning of the Republic of Lithuania (Procedure for Turning Forest Land into Land for Other Purposes, Official Gazette *Valstybės Žinios*, 14 05 2002, No. 48-1840). A forest owner or forest user who wishes to turn forest land into land for other purposes must submit a request to the county governor.

Stabatiškė site is not located within the shore protective strip of surface water bodies, or in the physical protection zone of heritage objects, or in a reserve. Therefore, there could not be any principal reasons that would not allow changing the purpose of land.

COMPARISON OF THE SOCIAL-ECONOMIC ENVIRONMENT OF THE SITES

1. Apvardai and Galilaukė sites are dominated by agriculture close to organic agriculture, local natural resources are used only for the organic bioproduction sector and non-intensive recreation. The economic and resource significance of the sites is low, of a micro-local level. Apvardai site is most favourable for the development of the bioproduction sector and it has the greatest potential.

2. Apvardai site is mostly reclaimed and more easily accessible; it has a greater potential of ecological big-scale farming and more land-ownership vicinities; therefore, there is a higher likelihood of interest conflicts with the owners and users of land within the perimeter.

3. The region is scarcely populated; however, there are settlements with permanent residents within the perimeter of the sites. The surroundings of Apvardai and Galilaukė sites suffered a rapid depopulation. The social situation of population is similar. There are no residents within the surroundings of Stabatiškė site. Non-local residents (mainly those of Visaginas) permanently or seasonally reside in the immediate surroundings of Apvardai and Galilaukė sites.

4. Material investments in the vicinities of Apvardai and Galilaukė are directed only towards repairs of homestead places. Real estate supply exceeds demand on Apvardai and Galilaukė sites but the situation in their vicinities (in the settlements by water bodies) is contrary. There is no land market. The development of the recreational sector and related businesses on the sites and in their immediate surroundings is mostly limited by a lack of water bodies suitable for these purposes.

5. The neighbouring border habitat of Belarus is dominated by the low-intensity bioproduction sector, the development possibilities of which are unfavourable due to low-productivity land, insufficient cultivation, and the remoteness of the habitat.

4.2 Potential Conventional Impact on the Natural and Human Environment

4.2.1. Water

Potential Impact on the Surface Water Resources and Formation of Sewerage

Construction of the repository will require drinking water, household water and water used for construction needs. Surface water may be used for construction (approximately 1 m^3/d), which may be sourced from the Druksta River (in case Galilauke site is selected), or from Druksiai or Apvardai lakes. In case Stabatiske site is selected, the water may be sourced from a pond planned in the north-eastern part of the site. Part of the surface water may also be sourced from the channels in the vicinity of the sites.

During the exploitation of the near surface repository (radioactive waste disposal stage) both drinking and household water will be necessary to meet the needs of the administration and service personnel, for the laboratory‘s work, for washing and decontamination of the transportation vehicles, and for fire safety purposes. At this stage the demand for water would approximate 13 m^3/d. Should it be decided that the water be supplied to the residents of the areas surrounding Galilauke site, water consumption would increase to 17 m^3/d. A smaller amount of water (2 m^3/d without supplying local residents or 6,0 m^3/d, including supply of water to the local residents) will be needed once the near surface repository is sealed (repository maintenance stage) – only drinking and household water for the needs of the maintenance personnel and for fire safety purposes (see Table 4.2.1.1).

Table 4.2.1.1. Water demand

Technological Process	Water source (supplier)	Raw water consumption, m^3/d			
		In total	Household needs	Industrial Use	
				Ground water	Surface water
Construction stage	Lakes and bores*	3,0	2,0	-	1,0
Waste disposal stage	Bores*	13,0	8,0	5,0	-
Maintenance stage	Bores*	2,0	2,0	-	-

* In case of Apvardai and Galilauke – a local bore, in case of Stabatiske – Visaginas water supply station.

No water supply installations are available in Galilauke and Apvardai sites. Therefore, water supply problems will have to be addressed already in the construction stage. Water supply system should be local (by drilling a local bore). Bore and water supply systems and installations will be detailed during the preparation of the technical project. Attention should be paid to the fact that the construction of the radioactive waste repository and its operation could change the ground water regime in the vicinity of the site, which may result in the reduction of the debit of shaft wells in the surroundings of the repository. Therefore, several local residents having shaft wells in the vicinity of Galilauke site could be connected to the radioactive waste repository‘s water supply system. There is no such problem in Apvardai site. In the case of Galilauke, the ground water bore could be drilled into the inter-morenic horizon, where the quality of water, according to the hydrochemical investigation of bore 20610, complies with the drinking water requirements (Table 4.2.1.2). The exploitation bore belongs to Group I water supply stations, which, in accordance with the requirements of HN 44:2003, must possess a 5 meter sanitary protection zone (strict regime protection zone) and a 50 meter buffering protection zone (3rd Sanitary Protection Zone).

Table 4.2.1.2. Chemical Composition of Water in Bore 20610

	Aquiferous horizons (bore filter interval, m)		
	Q (48-53)	**Q (67-75)**	**D3-2 (113-123)**
B. soft, mg/l	339,6	365,1	284,2
B. hard, mol/m³	4,49	4,68	4,20
Permanganate number O2/l	8,0	7,68	5,12
Cl^- , mg/l	5	5	7
SO_4^{-2}, mg/l	1	1	3
HCO_3^-, mg/l	394	436	326
CO_3^-, mg/l	<4	<4	<4
NO_2^- , mg/l	0,03	0,03	0,05
NO_3^- , mg/l	5	<3	4
Na^++K^+, mg/l	51	61	39
Mg^{2+}, mg/l	17	23	20
Fe^{2+}, mg/l	0,53	0,74	0,53
Fe^{3+}, mg/l	1,05	0,32	1,58
NH^{4+}, mg/l	<4	<4	<4

Transportation vehicles and construction mechanisms will be used for construction of the repository. Only very insignificant pollution is possible due to a fuel spill-out from the transportation vehicles and other mechanisms or due to the storage of construction materials. An orderly exploitation of the mechanisms should prevent any fuel leakage or other environmental pollution. Natural materials (clay, sand, silt sand, rocks and gravel) will be used in the construction process; therefore, their storage and utilisation will not have an impact on the quality of water. Massive Ferro concrete, concrete, wooden and plastic construction materials as well as glass will also be used in the construction process. All of these materials are inertious in terms of their environmental impact.

The repository, its protection zones and auxiliary structures may occupy up to 40 ha, of which 10 ha will be occupied by the repository itself. The annual amount of unpolluted waste water (rain water) generated in this territory will comprise 2600 thousand m³. This waste water will not be very polluted due to a small number of mechanisms used and limited activities within the territory.The discharged surface waste water will be controlled in order to assure that the amount of sunk materials, BDS_7 and oil products do not exceed the limits specified in Surface Water Treatment Regulation (*Surface Water Treatment Regulation adopted by Order D1-193 of the Minister of Environment of the Republic of Lithuania on April 2, 2007*).

Table 4.2.1.4. Waste Water Balance

Waste water source, technological process	Total amount of waste water generated	Discharged					Directed for reutilisation			
		Household		Industrial		Surface	At this site		At other sites	
	m^3/y	m^3/d	m^3/y	m^3/d	m^3/y	m^3/y	m^3/d	m^3/y	m^3/d	m^3/y
Construction stage	4940780	2	520	1	260	4940000	-	-	-	-
Waste disposal stage	4943380	8	2080	5	1300	4940000	-	-	-	-
Maintenance stage	4940520	2	520	-	-	4940000	-	-	-	-

A small amount of household waste water may be generated during the construction, disposal and maintenance stages (Table 4.2.1.4). The household waste water may be polluted with organic elements, phosphate and nitrogen compounds. Therefore, they will be treated in local biological treatment facilities (in case of Apvardai or Galilauke sites) or in Visaginas water treatment facilities (Stabatiske site).

Waste Water Treatment and Measures to Reduce Environmental Impact

Plans are to construct a near surface barrow-type repository set up above the ground water stratification level. Particular attention will be paid to the effectiveness of the drainage system. A temporary vault drainage system will be operational during the construction of the repository‘s vaults and their loading with the radioactive waste. At that time, the waste packages will be in tact, and the radionuclides will not be discharged into water. Upon sealing of the repository, this drainage system will be removed and a long-term vault cover drainage system will be installed (*Procedures and techniques ..., 2001*). Upon sealing of the repository, the rain water will flow to the trenches installed in the bottom of the slope. In order to prevent moisture of the vault foundations, laying of a water-permeable soil (sand or gravel) layer, utilisation of anti-corrosive (ceramic) drainage pipes and installation of wide trenches filled with sand, gravel or stone will take place, which will allow for drainage of water into irrigation channels, a river or a lake. (*Rimidis A., 2005*).

The impact of the repository‘s construction, exploitation and maintenance on water may be as follows: waste water from washing of transportation vehicles, emergency spill-out of vehicle fuel or oil at the construction site, in the access roads and in the parking lots as well as household waste water. The pollution of the territory‘s surface will be insignificant as the anticipated exploitation equipment will not be complex, the operations performed in the process of cargo transportation will be simple and fully automated, and the number of installations used will be small. Surface waste water will be collected and treated separately from the household and industrial waste water. Surface water occurring at the unloading site and at the vehicle washing site will be collected and control measurements to determine pollution level will be performed. Separate parts of the drainage system will collect surface water from the repository and the developed territory. If no abnormal pollution concentration is found in the waste water, they are discharged into the channels (*Surface Water Treatment Regulation adopted by Order D1-193 of the Minister of Environment of the Republic of Lithuania on April 2, 2007*).

Water used for showering, sanitary cleaning and for decontamination of the installations and vehicles will be collected into a waste water reservoir. Upon the inspection of its radioactiveness (see Chapter 6 Monitoring Programme), water will be discharged to the water treatment facilities, provided that the radioactiveness of radionuclides does not exceed the levels established in the detailed environmental monitoring programme. Should these levels be exceeded, the water will be transported to the radioactive waste treatment facilities in Ignalina Nuclear Power Plant.

Household and industrial waste water will be treated in the waste water treatment facilities up to the quality sufficient to discharge them into irrigation channels or the Druksa River or a lake. Local water treatment facilities for the treatment of household wastewater capable of treating water up to the permissible level should be installed at Apvardai or Galilauke sites. After the treatment, the waste water would be discharged into the irrigation channels (see pictures 4.2.1.1 and 4.2.1.2).

In order to prevent a spill-out of pollutants into the water basins, the following preventive measures will be applied:

1. Surface waste water collection and monitoring system will be installed in the constructed site, access roads and parking lots;

2. Surface waste water collection system will be designed in such way as to enable collection of pollutants and their removal or discharge to the local treatment facilities in case of emergency;

3. Pollution spill-out liquidation plans will be prepared and the personnel will be acquainted with them and trained how to act in emergency situations;

4. Household waste water will be treated in the biological treatment facilities;

5. The quality of the discharged waste water will be monitored in accordance with the established procedure.

Surface waste water monitoring system will be installed in the radioactive waste repository and its execution programme will be prepared. Water monitoring will assure on-going control of the surface and household waste water.

GALILAUKE SITE

Water of water basins and ground water of Galilauke site belongs to the calcio-hydrocarbonate water type. Estimated base data is specified in Chapter 4.1.1. Significant quantities of chlorides, phosphates, nitrogen and organic elements were found in Gulbinele and K-2 channel. This indicates that insufficiently treated household waste water is discharged from Visaginas waste water treatment facilities. The overall quantity of phosphate in Gulbinele exceeded even the maximum permissible level. Relatively high quantities chlorides, nitrates, and general nitrogen were also found in bore 5 and K-12 channel. Water in the surface water basins does not comply with the drinking water requirements in terms of nitrogen and phosphate concentrations and the quantities of organic substances. The ground water in some of the bores also does not comply with the drinking water requirements in accordance with the tested parameters.

Household waste water generated at the site during the exploitation should be treated in the locally installed biological treatment facilities, and treated waste water should be discharged into an irrigation channel located in the southern part (Picture 4.2.1.1). Monitoring of the surface water should be performed below the discharge site.

APVARDAI SITE

The drinking water source that is closest to Apvardai site is Visaginas water supply station located 4 km away if measured in straight line. Drilling of an exploitation water bore in the territory of the site or in its surroundings would be the best solution for meeting the drinking water needs. If necessary, water supply from this bore could also be made available to the local residents.

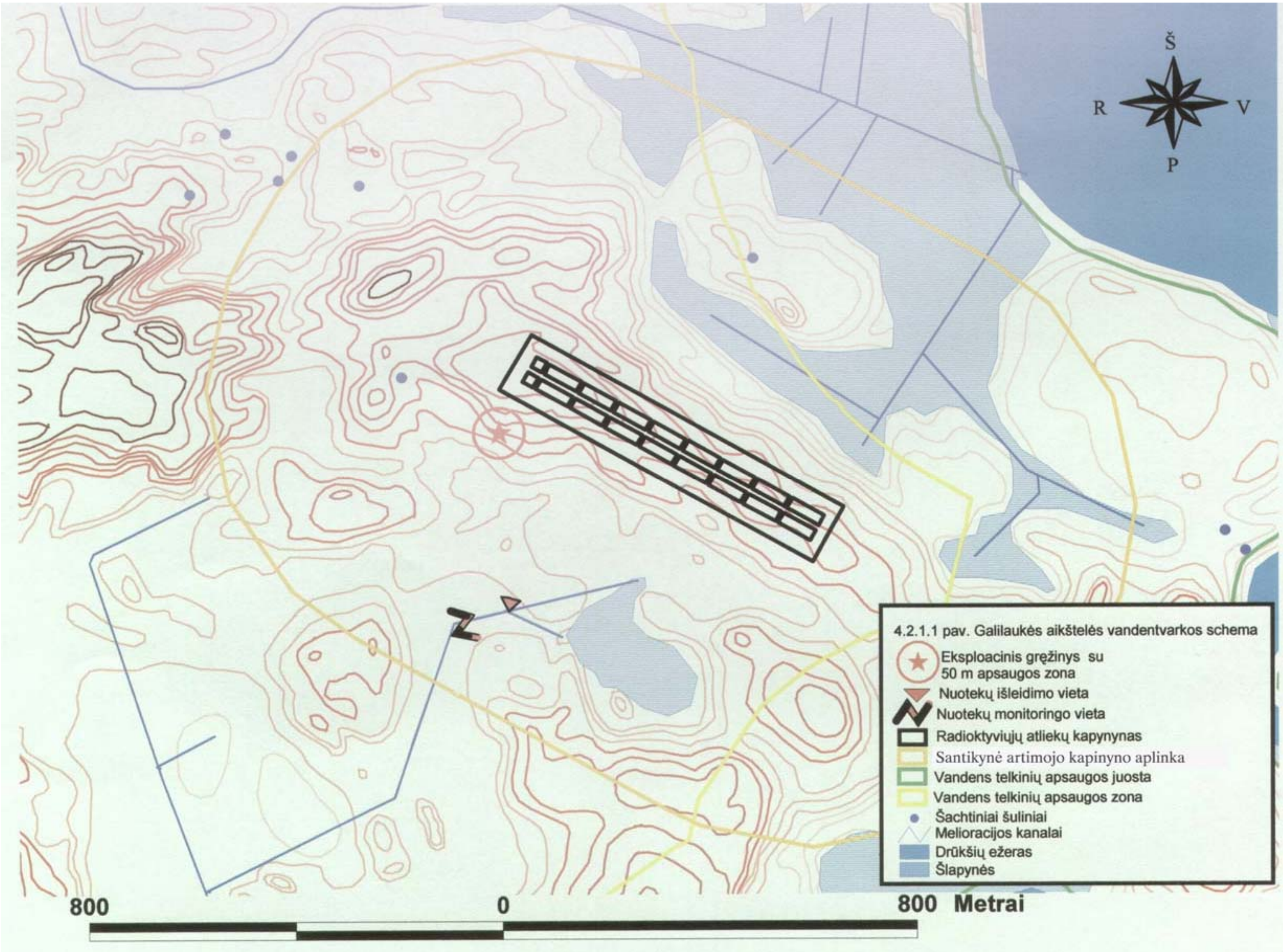
Water of water basins and ground water of Apvardai site belongs to the calcio-hydrocarbonate water type. The quantities of biogenic and organic substances in this water are lower than in Galilauke or Stabatiske sites; however, even here the surface and the ground water do not meet the drinking water requirements in terms of nitrogen and phosphate compound concentrations. The resources and the quality of the surface and ground water in the surroundings of the site are not sufficient for meeting the repository‘s water needs.

Household waste water generated at Apvardai site during the exploitation should be treated in the locally installed biological treatment facilities, and treated waste water should be discharged into an irrigation channel located in the southern part (Picture 4.2.1.2). Monitoring of the surface water should be performed below the discharge site.

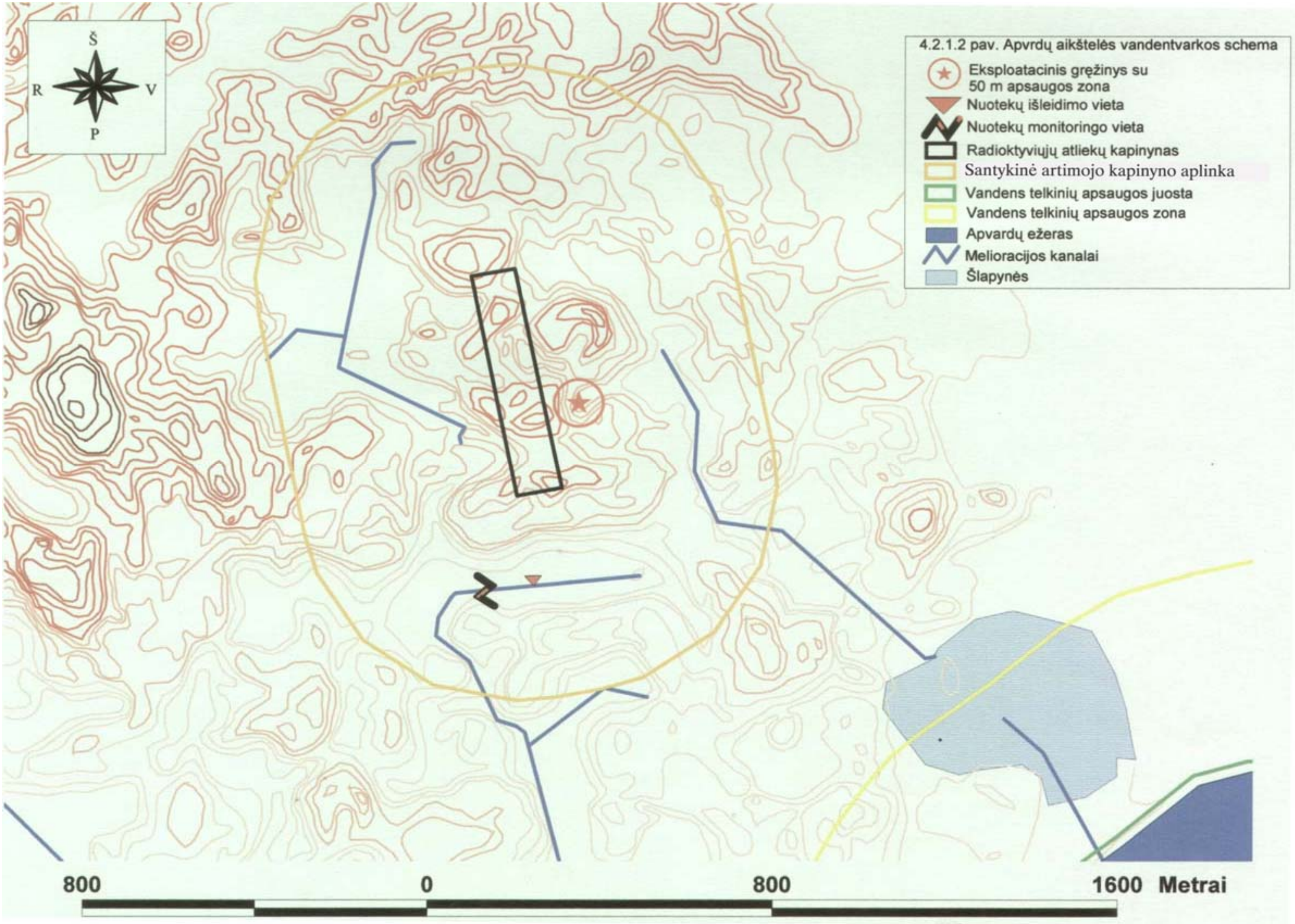
STABATISKE SITE

Water of water basins and ground water of Stabatiske site also belongs to the calcio-hydrocarbonate water type. Rather high concentrations of biogenic substances were found in some of the site‘s surface water basins and bores. Water of such quality stimulates eutrophication processes if discharged to the surface water basins. This, probably, is related to residual pollution of the territory and high quantity of organic substances in the wetlands.

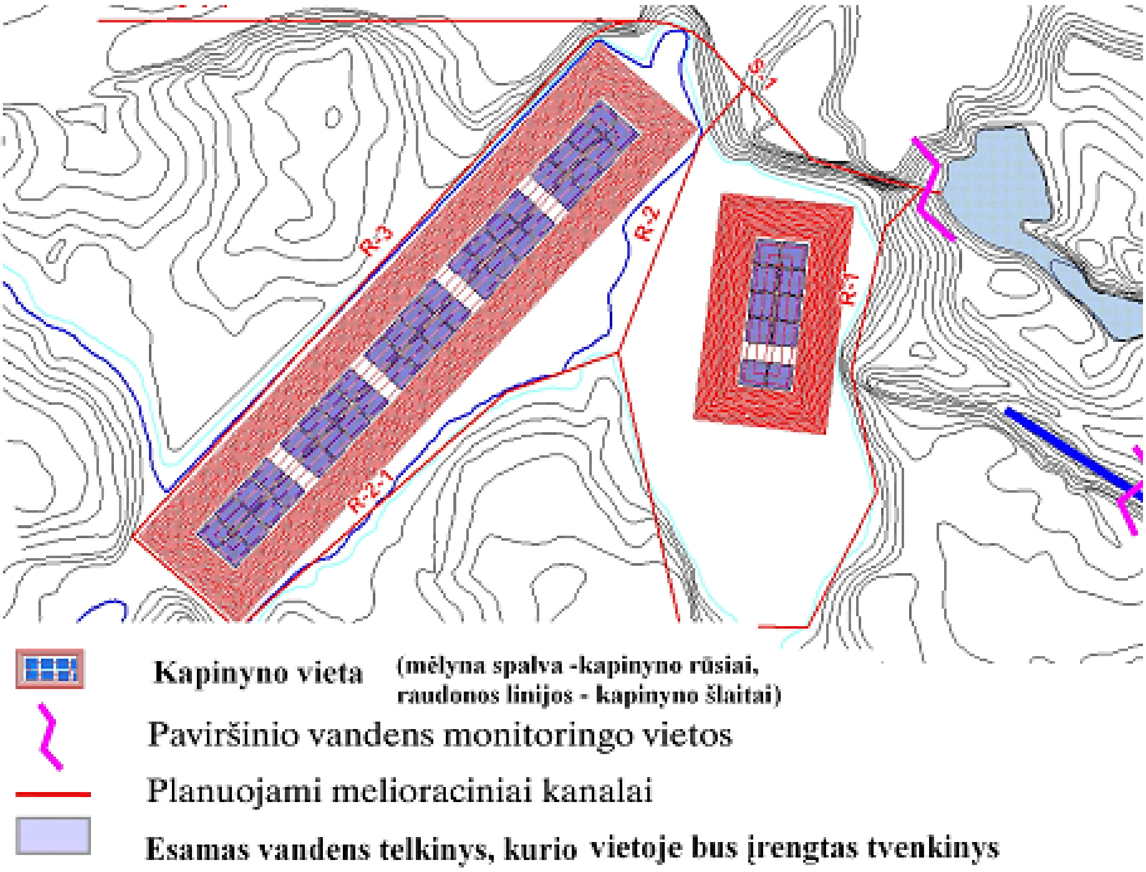
Household waste water generated at the site during the exploitation should be discharged to the waste water network of Ignalina Nuclear Power Plant which runs nearby, and should be treated at the waste water treatment facilities located at Skripku Lake. An entirely new drainage system adapted to the needs of the repository should be designed and installed at the site prior to the construction of the repository. (Picture 4.2.1.3).



Picture 4.2.1.1 Water Supply Management Scheme at Galilauke Site. Legend definitions (from top down): a) exploitation bore with a 50 meter protection zone; b) waste water discharge site; c) waste water monitoring site; d) radioactive waste repository; e) relative surrounding repository environment; f) water basins protection strip; g) water basins protection zone; h) shaft wells; i) irrigation channels; i) Druksiai Lake; j) wetlands



Picture 4.2.1.2 Water Supply Management Scheme at Apvardai Site. Legend definitions (from top down): a) exploitation bore with a 50 meter protection zone; b) waste water discharge site; c) waste water monitoring site; d) radioactive waste repository; e) relative surrounding repository environment; f) water basins protection strip; g) water basins protection zone; h) Apvardai Lake; i) irrigation channels; i) wetlands



Picture 4.2.1.3. Water Supply Management Scheme at Stabatiske Site.

Legend definitions (from top down): a) repository site (repository vaults are marked in blue, repository slopes – in red); b) surface water monitoring sites; c) planned irrigation channels; d) existing water basin which will be replaced with a pond.

4.2.2. Ambient Air

Ambient Air Pollution

Planned radioactive waste repository sites are distant from large urbanised territories, industrial centres or enterprises whose activities are related to the discharge of significant pollution quantities into the air. The nearest automated air quality monitoring station is in Panevezys. Although this station registers daily data, it reflects only the quality of Panevezys air. Regional air quality may be assessed on the basis of data from Aukstaitija (LT01) station measuring ambient air quality. This station is in the National Park territory. Its location with respect to the urbanised territories and large scale industrial sites is similar to that of Galilauke and Apvardai sites.

In LT01 station, as in other ambient air monitoring stations, the following concentrations of gas and aerosol pollutants were investigated: SO_2 (gas), NO_2 (gas), SO_4^{2} (aerosol particles), ΣNO_3^- (the sum of gaseous HNO_3 and aerosol particles O_3^-) and ΣNH_4^+ (the sum of gaseous NH_3 and aerosol particles NH_4^+). Statistical investigation data is provided in Table 4.2.2.1.

Table 4.2.2.1. Statistical values of pollutant concentrations in the ambient air monitoring station LT01 in 2003 (data from the Environmental Protection Agency)

Pollutant	**Concentration C**			
	Minimum		**Maximum**	
SO_2	0,05	µg S / m³	0,1	µg / m³
NO_2	0,15	µg N / m³	0,5	µg / m³
SO_4^{2}-	0,23	µg S / m³	-	µg / m³
ΣNO_3^-	0,2	µg N / m³	-	µg / m³
ΣNH_4^+	0,31	µg N / m³	-	µg / m³

Fluctuations in sulphur dioxide and nitrogen dioxide concentrations carry a strong seasonal pattern. SO_2 concentration (4,55 µgS/ m³) was the highest in the first week of January. It exceeded the average annual concentration (0,77 µgS/ m³) during other winter weeks as well. Meanwhile, during spring – summer months, SO_2 concentration was frequently lower than 0,50 µgS/ m³.

Lower than the average annual (0,66 µgN/ m³) concentrations of nitrogen dioxide were recorded in summer and autumn months (from May to October), while higher than the average concentrations were recorded in winter months. The highest concentration - 2,16 µgN/ m³ – was during the first week of January. Seasonal fluctuation is not characteristic to the annual dynamic of the concentration of aerosol sulphates, the sum of nitrogen concentrations or the sum of ammonia concentrations. However, in summer months, these concentrations were frequently lower than or close to the average annual concentrations.

The average monthly concentrations of aerosol sulphates in January-March months were almost twice as high as the annual average. In June-September months, they fall several times. Data for the period between 1994 and 2003 indicates that the annual concentration of sulphur dioxide falls annually by approximately 0,19 µgS/ m³ per year. The concentration of aerosol sulphate falls by an average of 0,27 µgS/ m³ per year. Lowering of the concentration of these sulphur components in the ambient air is probably most attributable to a rather significant fall in SO_2 emissions in Western Europe. The annual concentrations of nitrate and ammonia sums fall by 0,007 µgN/ m³ and 0,22 µgN/ m³ per year, respectively. No changes were observed in the concentrations of NO_2.

When performing earth works at the sites and during the construction and exploitation, the pollution norms may not exceed the limits established by Order No. 591/640 Concerning Setting of Environmental Pollution Norms signed by the Ministers of Environment and Health on 11th December 2001. (Table 4.2.2.2).

Table 4.2.2.2. Ambient air pollution norms established in order to protect human health, ecosystems, and flora. Even reduction of limitary values with permissible deviations starting from 2002 (*Official Gazette*, 2001, No. 106-3827)

Pollutant		**SO_2**	**SO_2**	**SO_2**	**NO_2**	**NO_2**	**NO_X**	**KD_{10}**	**$KD_{2.5}$**	**CO**
Averaging time		**1 h**	**24 h**	**1 m., 1/2 m.**	**1 h**	**1 m**	**1 m**	**24 h**	**24 h**	**8 h**
Limitary value, µg/m³		**350 (24 times)**	**125 (24 times)**	**20 E**	**200 (18 times)**	**40**	**30 A**	**50 (35 times)**	**40 (14 times)**	**10 mg/m³**
Permissible deviation size		**150 µg/m³**	**-**	**-**	**50%**	**50%**	**-**	**50%**	**50%**	**6 mg/m³**
2002	**Limitary value + permissible deviation size**	463			289	58		69	58	16
2003		425			278	56		63	56	14
2004		388		20 E	267	53	30 A	56	53	12
2005		350	125		256	51		50	51	10
2006					245	49			49	
2007					233	47			47	
2008					222	45			45	
2009					211	42			42	
2010					200	40			40	

* - calendar year and winter (October 1 – March 31)
E – ecosystem protection
A – flora protection
(24 times), (25 days) – number of permissible overruns per calendar year

Ambient Air Pollution Forecast

APVARDAI AND GALILAUKE

Construction of the Repository

Earth works are the most important during the repository‘s construction stage. Concentration of heavy particles may increase to some extend in the site‘s surroundings during the performance of the earth works. The biggest quantities of heavy particles may be released into the air during ground digging, lorry loading and unloading, and transportation of the soil or construction materials. Estimating the quantity of heavy particles released into the environment is virtually impossible. The main reason is limited possibilities of accurately estimating the granuleometric consistence and humidity of the dug out soil.

An insignificant amount of pollutants will be released into the air from the internal combustion engines of the construction equipment. Concentrations of SO_2, CO_2, NO_x, CO may increase in the territory of the construction site, but they will not reach the values harmful to the environment.

Exploitation and Maintenance of the Repository

Plans are to dispose 100 000 m^3 of radioactive waste at the repository - approximately 21700 packages. Planned repository's exploitation period is 20 years. Four to five packages of radioactive waste will be delivered to the site per working day. Even if the packages were delivered one unit per day, the intensity of the transport would not increase significantly and the environmental impact would be minimal.

During the exploitation and maintenance of the repository, the administrative building, a temporary storage, and the auxiliary maintenance building will be heated with a local boiler. While the exact number of buildings and their size are not known, a preliminary estimate is that a boiler with 1 MW capacity would be sufficient to meet the energy needs.

No decision has been made yet as to whether the boiler will use organic fuel or electricity. If electricity is used, operation of the boiler will not cause ambient air pollution. If organic fuel is used, SO_2, CO_2, CO, NO_x and particulate matter would be released into the environment. Pollution emissions very much depend on the type of the organic fuel (Table 4.2.2.3).

Table 4.2.2.3. Pollution emissions from organic fuel required to produce 1 MW of energy, in kilograms (according to the data of United States Energy Information Administration)

Pollutant	Natural gas	Oil	Coal
CO	0,001	0,002	0,008
CO_2	0,181	0,254	0,322
NO_x	0,142	0,694	0,707
SO_2	0,001	1,737	4,011
Particulate matter	0,011	0,13	4,248

Natural gas is the least harmful to the environment organic fuel. In order to use this type of fuel, laying of a separate gas pipeline branch would be necessary. However, this would not be efficient for the boiler with such small capacity. Therefore, the boiler will be fuelled with oil (boiler oil) or coal.

The maximum concentrations of pollution near the ground and the distance of their formation from the boiler's chimney were estimated with the assistance of United States Environmental Protection Agency's model *Screen3*. This model is used for estimating the dispersion of ambient air pollution from the spot, area or volume source under the most unfavourable meteorological conditions.

The exact parameters of the boiler building (the height of the chimney and its diameter) and the combustion process (smoke temperature, the speeds of their discharge into the environment) are not known at the present. Therefore, the missing data was selected on the basis of analogous capacity boilers in USA and Canada. Depending on the boiler type, the speed of discharging the gas mix from the chimney varies in the interval between 1 m/s and 3 m/s, therefore, pollution dispersion was calculated for these marginal cases. Data used in the modelling of pollution dispersion is provided in Table 4.2.2.4.

Table 4.2.2.4. Data used in the modelling of pollution dispersion

Parameter	Fuel			
	Oil		Coal	
Speed of discharging gas mix	1	3	1	3

Parameter	Fuel			
	Oil		Coal	
from the chimney, m/s				
Chimney height, m	30	30	30	30
Chimney diameter, m	1	1	1	1
Smoke temperature, K	480	480	480	480
Ambient air temperature, K	280	280	280	280
CO emission, g/s	0,0006	0,0006	0,0022	0,0022
CO_2 emission, g/s	0,0705	0,0705	0,0894	0,0894
NO_x emission, g/s	0,1927	0,1927	0,1965	0,1965
SO_2 emission, g/s	0,4825	0,4825	1,1142	1,1142
Particulate matter emission, g/s	0,0361	0,0361	1,18	1,18

Based on the modelling outputs, the highest one hour concentrations when the speed of gas mix discharge from the chimney is 1 and 3 m/s, will be 239 meters and 342 meters from the chimney, respectively. Maximum one hour pollution concentrations (Table 4.2.2.5) (adding ambient pollution to the modelling results) will be at least several times lower than the limitary concentrations of these pollutants (Table 4.2.2.2) even if a longer period is taken into account.

Table 4.2.2.5. Pollution dispersal parameters

Speed of discharging gas mix from the chimney, m/s	**Fuel**			
	Oil		**Coal**	
	1	3	1	3
Distance where the concentration of discharged pollution will reach the maximum value near the ground, m	239	342	239	342
Maximum one hour concentration, µg/m^3				
CO	0,03	0,02	0,13	0,06
CO_2	3,95	1,91	5,03	2,42
NO_x	10,8	5,21	11,04	5,32
SO_2	27,04	13,04	62,6	30,18
Particulate matter	2,02	0,98	66,3	31,96

The environment would be most polluted with SO_2 and particulate matter if the boiler were to be fuelled with coal and the speed of discharging gas mix from the chimney would be 1 m/s. In this case, the maximum one hour concentration of the particulate matter, 66,30 µg/m^3, would exceed the limitary 24 hour average concentration of this pollutant (66,30 µg/m^3).

Plans are to install a parking lot for the repository‘s maintenance personnel. As the number of the employees is not high, the parking lot will exhibit no significant impact on the ambient air.

There may occur organic substances in the packages of radioactive waste, which produce gas when disintegrating. The disintegrating organic substances, however, will exhibit no impact on the ambient air as efforts will be made to reduce the amount of such substances during packaging of the radioactive waste and the construction of the repository‘s hill will be favourable to the dispersion of the formed gas.

STABATIŠKE SITE

Construction of the Repository

Concentration of heavy particles may increase to some extend in the site's surroundings during the performance of the earth works, lorry loading and unloading, and transportation of the soil or construction materials. Estimating the quantity of heavy particles released into the environment is virtually impossible.

An insignificant amount of pollutants will be released into the air from the internal combustion engines of the construction equipment. Concentrations of SO_2, CO_2, NO_x, CO may increase in the territory of the construction site, but they will not reach the values harmful to the environment.

Exploitation and Maintenance of the Repository

In case of Stabatiske site, the ambient air pollution will be minimal because:

1. Waste delivery distance will be reduced substantially,
2. The repository would be connected to the adjacent heat supply network and a local boiler would be unnecessary.

Impact Reduction Measures

In order to reduce discharge of dust particles into the ambient air which would exceed the permissible concentrations of particulate matter during earth and construction works, the following options are available: watering of the dug out soil, watering of non-paved roads, transporting soil and loose constructions materials in covered lorries, or loading them in such way as to leave at least several tenths of centimetres from the board side top.

If electricity is used to heat space and water in Apvardai and Galilauke sites, the ambient air would not be polluted. If organic fuel is selected as the source of energy, boiler fuel will produce less ambient air pollution relative to coal. In order to reduce the amount of pollution discharged into the environment, it is advisable to use boilers with a high efficiency coefficient. In order to reduce emission of particulate matter, the discharged gas could be filtered with an electrostatic particle catcher.

4.2.3. Relief, Soil and Geodynamic Processes

Potential (Forecasted) Impact

Potential impact on soil. In order to construct the repository, repository's buildings and the necessary infrastructure (laying of the roads), plans are to remove approximately 15000 m^3 of fertile soil. The biggest part of the soil will be removed while installing the repository with the rest being removed due to the construction of the buildings and infrastructure installation. Approximately 0,5 ha lot will be needed for storage of the removed soil layer.

Potential impact on the relief. Several mounds will be removed during construction of the repository – up to 490 000 m^3 of ground in a 10 ha territory. Since a technogenic site will be formed and all processes taking place inside of it and on its surface will be controlled by humans, the impact on the geodynamic processes will be insignificant, while potential activation of the processes will be controlled.

In the instance of Galilauke site, a technogenic site will be formed in place of a natural mound. However, in terms of the relief's landscape, the exterior of the mound will change only slightly – upon the completion of the disposal of the radioactive waste, the mound will be covered thus increasing its height. In the instance of Stabatiske site, the existing mounds would be heightened while a pond would be formed in the north-eastern corner of the site.

Temporary storage of the dug out ground and soil may result in formation of mounds (if the ground is poured into one spot in a 5 meter thick layer, 2 ha of the territory would be used). Formed mounds could have a local impact on the surface water flow and on the geodynamic processes.

Impact Reduction Measures

Soil protection. Paragraph 6 of Article 9 of the Law on Land (No. 1-446, adopted on 26th April 1994) requires that the fertile soil layer be protected and damaged land be recultivated. Article 39 specifies that the fertile soil layer may not be destroyed during the construction process but rather used for improving of the agricultural land.

Upon the completion of the repository's construction works, most of the removed fertile soil will be utilised within the site's territory. The remaining soil should be used for recultivation of other territories and for improving of eroded soil qualities.

In order to minimise impact on the ecosystem of Apvardai Lake at Apvardai site, we propose installing a temporary fertile soil storage lot to the north-west of the planned repository's site. The soil could be removed from the site to the recultivated areas already at the time of the repository's construction.

In order to minimise impact on the ecosystems of Druksiai Lake and Druksa River at Galilauke site, we propose installing a temporary fertile soil storage lot to the west of the planned repository's site.

At Stabatiske site, the soil storage lot could be situated to the west of the construction site.

Relief protection. As already noted, construction of the repository would damage the internal structure of Apvardai site's mound (referred to as Miksto Mound). In order to compensate internal and external damage distorting the landscape, it would be purposeful to preserve the shape of the mounds (where possible in terms of technological capabilities). Since the Miksto Mound and surrounding mounds possess more complex internal and surface structures relative to Galilauke site, including microrelief forms, restoration of such forms would not be purposeful.

Piling of large removed ground terikons should be avoided where possible. In terms of environmental protection, the most acceptable solution would be to use the removed ground for installation of the repository or for laying of the necessary roads. If this is not possible, unutilised removed ground should be utilised in other construction sites.

4.2.4. Earth Depths

Potential (Forecasted) Impact

If, during the construction process, the foundations need to be installed below the ground water level, lowering of the ground water level may be necessary (depending on the depth of the foundations). However, having regard for the topographic situation, lowering of the ground water level will be minimal and thus will not bear any impact on the regime of the surrounding ground water.

No vibrations are foreseen during the exploitation period, therefore the mechanical qualities of the ground layers should not be worsened due to the dynamic load.

Potential Impact of Geological Environment Changes Caused by the Repository‘s Construction On Other Components of the Environment

No activation of geological processes is foreseen during the construction period. Therefore, the potential impact of geological environment changes caused by the repository‘s construction on other components of the environment should be minimal.

If the ground water level is lowered during construction and exploitation, this may result in the potential lowering of the ground water in the surrounding surface water basins (streams, irrigation channels, wetlands).

Impact Reduction Measures

Impact prevention measure – appropriate engineering structure of the repository.

4.2.5. Biological Diversity

Potential (Forecasted) Impact

One bird species from the Red Book of Lithuania – the corn crake - is registered next to Apvardai and Galilauke sites. The impact of the repository‘s construction and its exploitation will not cause damage to the endangered wild flora and fauna species habitats: no endangered flora species were found, while the habitats of corn crakes are irregular and may change on the annual basis. The particularities of the corn crake habitats may be derived from the following arguments: the environment favourable for corn crake breeding includes the entire field-meadow space around the habitat of the repository; a corn crake is known for mobility and easily migrates to nearby suitable locations; the area of the repository is very small compared to wide neighbouring biotypes suitable for corn crakes; upon the completion of the construction, the level of noise will come down and corn crakes will be able to reside and breed immediately next to the repository‘s fence.

The habitat of the site and the entire repository is not a site for fauna concentration, rest, hibernation and does not stand on its migration routes.

Early-Marsh orchid habitat discovered at Galilauke site will not be physically damaged as it is situated within a sufficiently long distance from the construction site. This type of orchid is one of the most popular types of orchid species in entire Lithuania. It is widely dispersed in wet meadows and irrigation channels throughout the country.

During the construction period, mound surfaces, slopes and a strip of a certain width around them may be transformed by removing the existing flora.

Wild fauna, flora and insect species found at Stabatiske site are regular and plentiful throughout the territory of entire Lithuania, and the planned activities will not damage them. Intensive spring migrations and migrations of new born from the spawning grounds are characteristic of toads and frogs. Therefore, these species may be exposed to a double threat: destruction or pollution of the spawning grounds and direct massive destruction of the individuals during migrations as well as perishing of separate individuals during the summer feeding season.

Discovered amphibian species are plentiful in Lithuania and the planned activities will not have an impact on their population in Lithuania. However, in order to minimise the impact on the nature, it is purposeful to erect barriers next to the roads, which would prevent the amphibian species from entering forest ponds and protect them during migration (particularly during the construction period). The most problematic is the situation of European Fire-bellied Toad species. This species falls under the category of strictly protected species in accordance with the EU habitat directives. This species was not discovered in the territory of the site during the survey. However, it does have a habitat in the immediate neighbourhood. Performance of earth works could endanger individuals residing in the surroundings. Therefore, if observed, fire-bellied toads should be removed to other suitable territories in spring time, prior to starting works.

Performed biological diversity surveys confirm that the southern bank of Dukstai Lake is a suitable location for constructing a near surface radioactive waste repository.

Impact Reduction Measures

There are no natural or relatively natural habitats at Apvardai and Galilauke sites. Therefore, application of natural habitat damage prevention and special damage reduction measures is not necessary.

As performance of earth works could endanger amphibian species residing in the immediate surroundings of Stabatiske site, if observed, fire-bellied toads should be removed to other suitable territories in spring time, prior to starting works.

4.2.6. Landscape

APVARDAI SITE

Potential (Forecasted) Impact

Due to the predominance of meadows and pastures, the landscape of the site exhibits a highly natural appearance – upon the construction of the repository, this natural appearance will be reduced and technogenised. In terms of the socio-ecological perspective, the landscape possesses no unique value which should be protected or conservated. In terms of the aesthetic perspective, the impact of the repository is ambiguous: on one hand, the natural appearance of the landscape will be reduced; on the other hand, its diversity will be increased.

When installing the site, the territory will undergo a transformation including changes to the vegetation structure and elimination of land crop areas; however, the aforementioned territory is not intensively utilised at the present (and will be utilised even less intensively in the future), therefore, there should be no shortage of the agricultural land. Furthermore, the number of individuals willing to undertake agricultural activities in the territory is dropping and may disappear altogether in several decades from now.

Impact Reduction Measures

The proposal is to change the concept of the repository and eliminate use of boulders. The surface of the boulders is not natural and is not characteristic of the Lithuanian landscape. Furthermore, under Lithuanian climate conditions, a decision not to use the surface layer of boulders will increase stability of the repository‘s surface provided that the surface layer of boulders is replaced with perennial grass flora.

Upon the termination of the agricultural land use (after several decades), it would be purposeful to split the surrounding territory with forest greenery thus increasing the socio-ecological stability.

The complex of buildings should be designed and constructed in such way as to make them optimally coherent with the landscape (by harmonising the height, form and construction materials used).

It is advisable to preserve a landscape element that contains a geo-ecological value – small Kumpiu forest located in the north of the main repository‘s mound.

Construction of the site should not incur damage (in terms of ecosystem stability and functioning of the natural carcass) to the wetlands – the hydrological regimes of the southern wetland (surrounding Apvardai Lake) and eastern wetland (situated along Gaide stream).

Construction and exploitation of the site should not prevent access to the surrounding mounds in north-west – Supakalnio and Klevo mounds, which present some of the most spectacular sightseeing opportunities in the region.

GALILAUKE SITE

Potential (Forecasted) Impact

Due to the predominance of meadows and pastures, the landscape of the site exhibits a highly natural appearance – upon the construction of the repository, this natural appearance will be reduced and technogenised. The territory of the site itself bears low to medium sensitivity to the technogenic impact and its landscape possesses no unique value which should be protected or conservated. Therefore, in terms of the ecologic perspective, the transformation of the landscape in the site‘s territory will not produce an impact of any significance on the landscape complex of the surroundings. In terms of the aesthetic perspective, the impact of the repository is ambiguous: on one hand, the natural appearance of the landscape will be reduced; on the other hand, its diversity will be increased.

When installing the site, the territory will undergo a transformation including changes to the vegetation structure and elimination of land crop areas; however, the aforementioned territory is not intensively utilised at the present (and will be utilised even less intensively in the future), therefore, there should be no shortage of the agricultural land. Furthermore, the number of individuals willing to undertake agricultural activities in the territory is dropping and may disappear altogether some 20 years from now, leaving only sporadic spots of activity .

Impact Reduction Measures

The proposal is to change the concept of the repository and eliminate use of boulders. The surface of the boulders is not natural and is not characteristic of the Lithuanian landscape. Furthermore, under Lithuanian climate conditions, a decision not to use the surface layer of boulders will increase stability of the repository‘s surface provided that the surface layer of boulders is replaced with perennial grass flora.

Since the view from Galilauke mound carries high values, efforts should be made upon the completion of the disposal stage, to shape the repository in the resemblance of the previous mound. This would allow to preserve the sightseeing potential of the mound.

In terms of the landscape protection perspective, the repository should be designed and constructed in such way as not to damage the water regime of a natural wetland situated to the north of Vosyliskes-Macionys road.

Upon the termination of the agricultural land use (after several decades), it would be purposeful to reforest the surrounding territory thus increasing the socio-ecological stability.

STABATIŠKĖS AIKŠTELĖ

Potential (Forecasted) Impact

The northern part of the site will be drained and the bushes and trees removed during the construction of the repository. In the north-eastern corner of the site, the existing mere will be replaced with a pond – water collector thus increasing the aesthetical value of the complex.

The site‘s territory has low sensitivity to the technogenic impact and its landscape has no special value. Local transformation of the landscape within the site‘s territory will not an impact of any significance to the landscape complex of the surroundings.

Impact Reduction Measures

The proposal is to change the concept of the repository and eliminate use of boulders. The surface of the boulders is not natural and is not characteristic of the Lithuanian landscape – which is one of the reasons for replacing the boulder surface with perennial grass flora.

4.2.7. Protected Areas, Ecological Networks and Objects of Heritage

APVARDAI SITE

Potential (Forecasted) Impact

Potential impact on protected areas. There are no protected areas in the vicinity of the site, therefore no repository‘s construction and operation impact on the protected areas is expected.

Potential impact on ecological networks. The site‘s territory does not belong to the territories covered by the ecological networks, therefore no impact on the ecological networks is expected.

Potential impact on historic, archaeological heritage and other immovable cultural heritage. There is no data on the existence of historic, cultural or archaeological heritage at Apvardai site, and no impact is expected on the heritage objects located closest to the site.

Impact Reduction Measures

No impact reduction measures are necessary. Upholding of the general environmental protection principles would be sufficient while constructing and exploiting the repository at this site. Special immovable cultural heritage protection measures are not necessary.

GALILAUKE SITE

Potential (Forecasted) Impact

Potential impact on protected areas. There are no protected areas in the vicinity of the site, therefore no repository‘s construction and operation impact on the protected areas is expected.

Potential impact on ecological networks. Construction of the repository and its exploitation will increase the area of degraded territories at the geo-ecological ridge of regional importance, which already occupy a significant part of the territory on the southern bank of Druksiai Lake (due to activities of Ignalina Nuclear Power Plant and Visaginas city). Consequently, fragmentation of the natural carcass will also increase. However, the impact on the ecosystem itself will be essentially local in nature.

The most important ecological elements located in the near surroundings and included in the ecological networks are Druksiai Lake and Druksa River ecosystems.

According to the EUwide network of protected nature territories Natura 2000, Druksiai Lake is designated as a territory where endangered bird species are protected (little crake, spotted crake, white tailed sea eagle, marsh harrier, great bittern). Construction and exploitation of the repository will result in the local impact of deterring noise. However, the planned construction site is sufficiently far from the Natura 2000 territory (Druksiai Lake), and, therefore, will have impact neither during construction nor during exploitation.

Potential impact on historic, archaeological heritage and other immovable cultural heritage. There is no data on the existence of historic, cultural or archaeological heritage at Galilauke site, and no impact is expected on the heritage objects located closest to the site.

Impact Reduction Measures

In order to reduce the impact of deterring noise, use of less noisy equipment is advisable. Also, where possible, construction and excavation works should be concentrated on the western part of the site, i.e., further away from Druksa River and Druksiai Lake (e.g. storage of the excavated ground et cetera).

The width of the protective zones of Druksiai Lake and Druksa River is 500 meters from the shore. All works (provided there are any) performed in these zones must be planned in accordance with the laws of the Republic of Lithuania regulating activities in such zones.

No impact will be inflicted on the nearest heritage sites (closed cemetery in Macionys village and burial grounds for German soldiers deceased in 1914 in Svikscionys village), therefore special cultural heritage protection measures are not necessary.

STABATISKE SITE

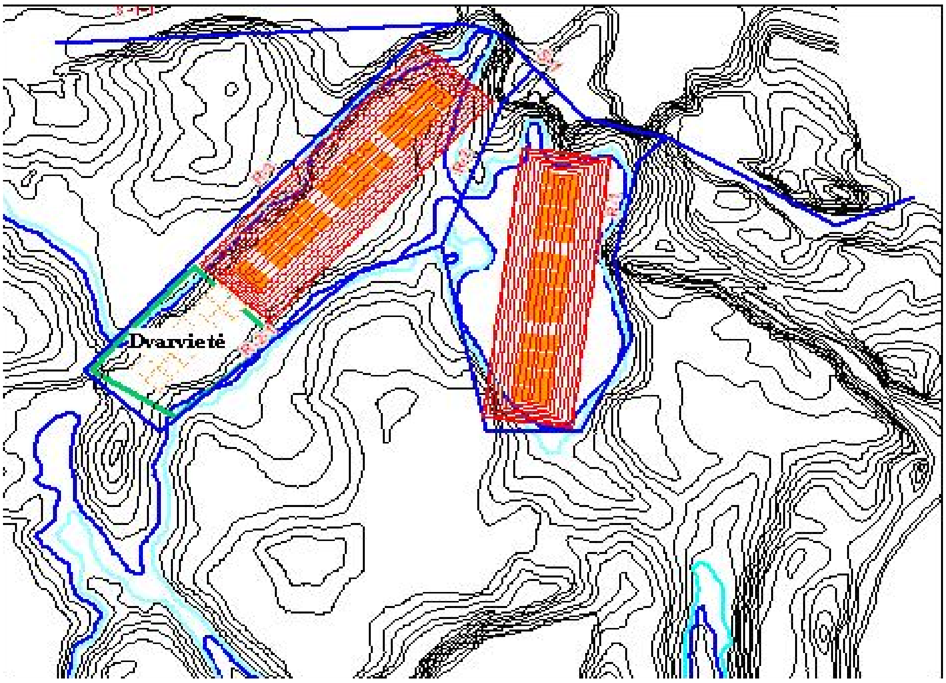
Potential (Forecasted) Impact

Potential impact on protected areas. There are no protected areas in the vicinity of the site, therefore no repository‘s construction and operation impact on the protected areas is expected. *Potential impact on ecological networks*. The site‘s territory does not belong to the territories covered by the ecological networks, therefore no impact on the ecological networks is expected.

Potential impact on historic, archaeological heritage and other immovable cultural heritage. Supplementary archaeological investigations discovered Stabatiske Manor (village site) in the territory of the site (Picture 4.1.8.2). It would be demolished during the construction of the repository. The following actions are proposed in order to reduce the impact (*Concerning Stabatiske..., 2006*):

1. To change the technical parameters of the repository‘s design in such way that Stabatiske Manor (village site) is not damaged during construction; in this case, the eastern part of the repository‘s site could be increased at the expense of the western part. Picture 4.2.7.1 depicts a possible layout of the repository‘s vaults and protective layer slopes which would leave the manor‘s territory untouched. In this case, 50 vaults could be placed in the free territory of the site, without, however, leaving a reserve territory.

2. Should the construction site and the scope of construction works remain in tact, a full scientific archaeological investigation of Stabatiske Manor (village site) would be necessary. Approximately 0,6 ha area would have to be investigated (*Concerning Stabatiske..., 2006*).



Picture 4.2.7.1. Alternative scheme for the placement of the repository's vaults

Impact Reduction Measures

Upholding of the general environmental protection principles would be sufficient while constructing and exploiting the repository at this site.

4.2.8. Social and Economic Environment

The impact of the planned economic activities on the socio-economic environment is based on the analysis of the planned economic activities performed within the scope of the feasibility study. Therefore, the assessment of the impact on the socio-economic environment under current circumstances was performed on the level of assumptions.

Potential (Forecasted) Impact

Impact of acoustic noise. The level of acoustic noise in the living and working environment is regulated by the Lithuanian hygienic norm HN 33-1:2003 (*Hygienic Norm HN 33-1:2003, 2003*). The aforementioned norm stipulates that the equivalent noise level in the residential environment may not exceed 45 dB (decibels) during the day (6 a.m. to 6 p.m.) and may not exceed the overall maximum of 70 dB. In the evening time (6 p.m. to 10 p.m.), the limits are set at 50 dB and 65 dB, respectively, and at the night time (10 p.m. to 6 a.m.) - 45 dB and 60 dB, respectively. In the industrial environment (construction site), the noise level may not exceed 85 dB.

Noise level research performed in 2003 established that the noise level created by construction at similar construction sites (installation and exploitation oil extraction sites, where the level of noise is plausibly higher than at the repository‘s construction site), falls to 55 dB within the distance of 120 – 170 m from the construction site during the day time. Passage of heavy transport creates the noise level of approximately 80 dB next to the road.

A conclusion is made that the equivalent noise level caused by the construction of the near surface repository will not exceed the permissible norms in the nearest settlements (300 – 500 m). The noise created by transport will not exceed the norms either, provided that the technical project specifies laying of the access road within an appropriate distance from residential buildings in accordance with the sanitary requirements, and the roads are well maintained.

In terms of the noise reduction perspective, the most suitable access route is from the west, which passes the households of Vosiliskes village by keeping the distance of at least 200 meters.

Impact of the repository‘s construction on the territorial settlement system. The impact of the repository‘s construction on the territorial settlement system will be minimal, especially in the long period. Due to the demographic tendencies, existing settlements as permanent residential sites would disappear on their own, while only one homestead in Galilauke would have to be removed because of the repository‘s construction. Emergence of new settlements is highly doubtful because of the geographical location of both sites. Overall, the impact on the territorial settlement system should be considered as insignificant.

Should Sabatiske site be used for the construction of the repository, the planned economic activities shall have no impact on either the settlement system or on the composition of the residents.

Potential real estate market changes, impact of the repository on the investment attractiveness of the surrounding territories. Impact on the real estate market is possible through changes in the demand and supply of real estate, which are caused by various factors:

1. Removal of part of real estate from the market (reduction of the supply). In this instance, the expected impact is insignificant as state-owned land is predominant at both sites. Therefore, on the regional level, potential supply will be reduced to a small extent.

The impact will not materialise also because the demand for the real estate (land) in the territory of the sites is very low. The demand is higher for the real estate that can be adapted for recreational use, which is not available at the sites;

2. Changes in the demand for real estate due changes in its attractiveness. This impact is related to the image of the repository, which may cause a drop in value of the real estate located in the surroundings. This negative impact is possible on the objects existing in the surrounding environment – six settlements in Galilauke and five in Apvardai. On the other hand, the territory may become more attractive (the demand may increase) due to improved accessibility. Overall, the impact is viewed as slightly negative and insignificant on the regional level.

The overall impact on the entire real estate market and its prices will be insignificant as the market is not active and the real estate (land) is either not used or used with low intensity.

The impact on the investment attractiveness of the surrounding territories is viewed as similar to that of the real estate market because the two are mutually related. Potential reduction in the investment attractiveness due to the image of the repository would mostly affect potential investments in the recreational activities. Conditions for other economic activities would improve due to the improved accessibility. Overall, the impact is insignificant primarily because the territory had very low investment attractiveness at the time of the investigation.

At Sabatiske site, planned economic activities will have no impact on the real estate market. The planned economic activity will have no significant impact on the use of the surrounding territories, because these are dominated by already developed and technogenically damaged areas and roads. The planned economic activity will disrupt the use of the surrounding territories neither during the repository‘s construction nor during its exploitation because there are alternative access routes and the environment will retain its industrial nature even after the closure of the Ignalina NPP.

Potential changes in the economy structure and intensity in the nearest repository‘s surroundings. No impact on the economy structure in the nearest surroundings due to the exploitation of the repository is expected because the economic use of the territories has very low intensity and the number of residents and their demographic structure do not allow for positive expectations in the future. The impact of the external factors (EU assistance, macroeconomic development of Lithuania, development of Ignalina NPP and Visaginas, agricultural politics of Lithuania) on the intensity of use of the territories will be much more significant. In this case, the repository‘s impact should be viewed as insignificant.

The impact on the economy structure at Sabatiske site may be related to the change in the designation of the site‘s land, operation of the repository‘s infrastructure objects or reconstruction of roads. However, there are no grounds to view potential changes as bearing a negative impact on the economy, particularly in view of the anticipated closure of Ignalina NPP and potential economic use alternatives of the territory.

Changes in accessibility, quality and utilisation of local natural resources and potential for alternative utilisation of resources. The quality and accessibility of the local natural resources will not become worse due to the construction and exploitation of the repository because there is no anticipation of an external impact beyond the boundaries of the repository, which would negatively affect existing resources. On the other hand, there are no valuable natural resources in the environment of the potential repository sites, while the existing resources (agricultural resources) are of low value. Positive impact is forecasted with respect to the utilisation of the existing resources due to the improvement of the accessibility conditions.

New working places will be created during the implementation of the project, the number of which will be fluctuating throughout the implementation of the project. In the region, where the level of unemployment is recorded as one of the highest, while the wage level, on contrary, is the lowest (except for Ignalina NPP), such impact should be viewed as significantly positive. The quality of life of the surrounding residents (residing next to the site‘s perimeter) will improve in long term due to the development of the infrastructure, although a temporary negative impact can be anticipated in the initial construction and exploitation stages due to increased traffic flows and construction works. The latter impact can be anticipated in the settlements located next to the future transportation roads.

No existing public interest conflicts were identified. Installation of the repository will have no significant impact on the public conflicts. There may be a potential conflict with the community of the existing and temporarily residing residents who may view the repository as potentially hazardous site and its construction and exploitation as factors disrupting the regular life flow.

Use of Sabatiske site for the planned economic activity may cause incongruence of interests between the need to renaturalise land damaged by the industrial invasion and the need to convert the land purpose from the forestry to other uses. However, a deep-seated conflict of public interests is unlikely.

The planned economic activity will have no impact on the state, accessibility and use of the existing natural resources and cultural heritage monuments, except for insignificant losses of forestry land.

Some of Economic Nature Utilisation Alternatives

The importance of the economic habitat has already been discussed in the introductory part of Chapter 4.1. This section provides comparative economic information on alternative uses of nature at the repository‘s site (Table 4.2.8.1). Their qualities (cultivation of land crops, soil fertility, etc.) are similar; therefore, the parameters were not calculated for the individual sites.

Hypothetical scenarios were formed in accordance with the recommendations for the development of alternative economy in North Eastern Lithuania (*Ribašauskienė, Uždavinienė, 1999*). An optimistic scenario was selected without taking into regard such factors as exhaustion of land crops, lack of demand for production, natural catastrophes, etc. Technological changes having potential impact on the efficiency were also not taken into account.

An assumption may be drawn from the data in Table 4.2.8.1, that potential losses from the loss of production during the entire exploitation period are at least eight times lower than the relative value of the repository‘s structures.

Table 4.2.8.1. Preliminary comparative information about hypothetical indicative revenues under different nature utilisation scenarios (in current prices, in thousand litas/ 1 ha per 300 years)

Scenario	**Indicative revenue**	**Remarks**
Traditional multi-sector agriculture	98-130	Base agricultural land fertility– 34-35 points. Indicative revenues provided according to (Ribašauskienė, Uždavinienė, 1999)
Cereal crops	240	Average purchasing price of cereal crops – 400 litas, average current fertility – 20cnt/ha
Apple tree farm	1350	Average apple harvest – 6 tonnes/ha, wholesale price of hand picked apples– 0,75 litas/kg

Herb or spice farm	Up to 2160	For instance, cultivation of the pharmaceutical marguerite, when the average harvest – 0,6 tonnes/ha, while the sales price – 12 litas/kg; cultivation of valerian is more profitable; however, the conditions for growing valerian in damaged hills are not favourable
Forestry (without secondary uses)	74	Three forest utilisation cycles – each 100 years long; average timber quantity per 1 ha – 196 m^3, average industrial spruce and birch wood price – 126 Lt/ m^3 (according to www.medis.lt, 2004 No.1 (3); under the condition that all timber is suitable for industrial use).
Investments into construction of the repository	***Approx. 17814***	***One-off investment per 1 ha***

If the repository‘s construction is not started in time, additional radioactive waste storage expenses may reach approximately 103 million litas over the period of 2010-2030, while the hypothetical revenues from a 40 ha site necessary for the construction of the repository may vary between 0,4 million litas (traditional agriculture) and 8,6 million litas (hypothetical revenues from intensive cultivation of herb farming).

There are not many long-term economic activity alternatives with respect to the discussed sites, and all of them are related to bio-productive economic activities. The territories could be used as non-intensive agricultural (Galilauke) and non-intensive forestry (Stabatiske and Apvardai) sites. Due to the geographical location, existing human and natural resources, anticipation of some other more intensive economic activities is not realistic. None of the potential long-term alternatives will create value added sufficient to place the economic logic of the repository‘s construction in question.

An alternative to the planned economic activity at Sabatiske site could be only development of the protective forestry, which requires fundamental forestry management. On the municipal and regional level, the economic value of forestry in this territory is low, and the site is not suitable for recreational activities. Restoration of agricultural activities is not purposeful due to low fertility of the land, significant recultivation efforts required and geographical positioning (in the vicinity of Ignalina NPP). Even if the territory were used for agricultural activities, all of its indicators would grade it as land unfavourable for agriculture (both due to low fertility of the land – less than 27 points, and due to demographical indicators in the surroundings of the territory).

Measures to Reduce Negative Impact on Socio-Economic Environment

As the anticipated negative impact on the socio-economic environment is very low, no particular measures to reduce it are proposed. Mostly such measures would involve information and public awareness activities. General impact reduction measures correspond to those which are specified in other sections, i.e., all measures reducing impact on the natural environment (air, soil, water pollution, noise, etc.) will also reduce the negative impact on the socio-economic environment.

At Stabatiske site, the most effective potential impact reduction measure would effective forestry management in the areas unoccupied by the buildings and forestry expansion.

<u>Organisational measures.</u> No particular organisational measures are

recommended as the anticipated impact does not require them. All impact reduction measures may be organised through the organisations that are already executing the project.

Economic measures. There is no need to undertake any special economic measures.

Information measures. Residents must be informed about the repository‘s impact on the environment – planned works, their duration, environmental changes related to the construction (new buildings, roads, working places, etc.) - through local press and special publications. The main task of information measures is to avoid formation of a negative image of the repository and related negative impact on the attractiveness of the territory.

In order to avoid negative reactions of the local residents, it is necessary to build the residents‘ (particularly those living in the surroundings – both permanent residents and temporary visitors) awareness of the future project and its impact on the environment. Information must be delivered through local mass information means (information for Ignalina and Visaginas municipality residents) and through specialised publications which would be disseminated to the residents in the repository‘s surroundings and would be accessible to interested individuals in the municipal and neighbourhood centres as well as development agencies.

4.3 Possible effects of ionising radiation on the natural and social elements of the nature

4.3.1 Direct ionising radiation

Occupational exposure

This chapter presents general protective means, which are planned to be implemented to ensure the minimal occupational exposure doses, determined by the exploitation of the surface repository of the radioactive waste (based on (ALARA) principle). Moreover these doses shall not exceed threshold values, defined in the legal acts. This chapter also examines an occupational radiation protection because both occupational exposure doses and radiation protection are relevant to the features of ionising radiation of the shielding barriers, which are planned to be mounted in the repository, in the vehicles of the radioactive waste packages and in the temporary storage.

The occupational exposure is being minimized and the radiation protection is being ensured by using the shielding barriers, the remote-control equipment, the monitoring and measuring devices, ventilation, by rationally situating radioactive waste packages of different activities in the repository basements, not beginning to load radioactive waste packages into the new basement as long as well-stocked basement are not covered, by placing engineer barrier of the sidewalls of the well-stocked basements immediately and applying exploitation procedures, which ensure occupational radiation protection. These means decrease the doses rates and exposure period as well as they reduces occupational exposure for the whole period of the exploitation of the surface repository.

Threshold values of the doses

The occupational threshold effective dose limit is 100 mSv per 5 years. The maximum annual effective dose is 50 mSv *(Hygiene Standard HN 73-2001, 2002).* According to Lithuanian Hygiene Standard HN 87-2002 *(Hygiene Standard HN 87-2002, 2003)* the zone rooms, controlled by nuclear installations, are divided into three categories by the dose rate:

- Category I >56 μSv/h;
- Category II 12 – 56 μSv/h;
- Category III <12 μSv/h.

The dose can be lower then 12 μSv/h in the whole zone, controlled by the surface repository, except the basement, which is being exploited, temporary storage, which can be loaded with 20 containers, and the particular specified territory near the basement when the containers are being loaded into it. On the purpose to ensure as low as possible occupational exposure doses, all the operations inside the temporary storage and loading non-shielding casks into the exploitable basement will be performed by remote control. The driver, who drives the vehicle with the radioactive waste package from the Ignalina Nuclear Power Plant to the reception zone of the packages in the temporary storages, will have to go outdoors and to close the door of the temporary storage. The reception zone will be isolated from the storage zone of the packages by shielding barrier. The overhead crane, fitted in the temporary storage, will be driven by remote control. This crane will perform all the operations of the discharge, transportation and loading of the packages. The driver, who drives the vehicle with radioactive waste package from the packages exportation zone of the temporary storage (which is isolated from the storage zone of the packages by shielding barrier) to the final disposal zone near the exploitable basement, will have to leave the vehicle and the zone. The overhead crane, steered by remote control from the central control board, will take the radioactive waste package from the vehicle. The cameras will help operator to control all the operations of the transportation of the radioactive waste packages.

The calculations of the doses identifies that the radioactive waste packages will be transported from the Ignalina Nuclear Power Plant to the surface repository and to the territory of the repository by the same vehicle, which will be used for the transportation of the radioactive waste packages, cemented in the territory of the Ignalina Nuclear Power Plant. The platform of this lorry has stationary attached casks of the transportation on the top, and the radioactive waste package is being put up into this cask. The cover of the transportation cask consists of two flaps. They are being opened and closed by the spindles in remote manner. The dose rate cannot be higher then 10 mSv per hour at any point of the surface of the transportation cask, this rate can be higher then 2 mSv per hour only when the requirements of the safe transportation is satisfied *(Regulations for the Safe ..., 2004)* § 572(a); moreover, the dose rate shall not exceed 0.1 mSv per hour at any point 2 meters from the vertical planes represented outer lateral surface of the vehicle. *(Regulations for the Safe ..., 2004; § 572(c))*. The thickness of the lateral steel plates of the transportation cask is 39mm, and the thickness of the frontal steel plate, which shields the driver, is 45mm.

The contamination of the external surface of any radioactive waste package will never exceed the threshold values, defined in the regulations of the safe transportation *(Regulations for the Safe…, 2004; § 508, 509)*, because the contamination value of the temporary storage in the Ignalina Nuclear Power Plant will not exceed values fixed for the third category stations.

The values of the volumetric activity of the waste packages

The values of the volumetric activity of the cemented radioactive waste packages, given in the table 4.3.1.1, is being used to calculate the shielding barriers, the occupational exposure and the effective doses for the members of the critical group during the period of the repository exploitation, whereas this typical radionuclide spectrum is sufficient to prove that the values of the values of the exposure doses, caused by the repository exploitation, will not exceed neither threshold effective dose nor the values of the limited doses, defined in the Legal Acts of Lithuania. This typical radionuclide spectrum was used in the technical project of the cementation device of the liquid radioactive waste and temporary storage of the Ignalina Nuclear Power Plant, in the final safety analysis report *(Detailed design ..., 2004)* as well as in the Ministry of Environment report of the evaluation of the effect on the environment *(Cementation device ..., 2002)*. In fact, the calculations of the doses show that the contribution of the alpha beams to the total effective dose of the actinide is approximately 0.5% in the normal conditions of the repository exploitation, and less then 0.1% in the case of the extreme conditions. Therefore, this contribution can be not-evaluated. The contribution of the radio nuclides such as tritium, ^{14}C or ^{129}I is completely insignificant, comparing with the evaluative contribution of the radio nuclides. The evaluation of the possible additional contribution of other radio nuclides, basically ^{90}S and actinides, to the total effective dose has showed that the calculations of the doses, using this typical radionuclide spectrum, are fairly conservative.

Table 4.3.1.1. The values of the volumetric activity of the cemented radioactive waste packages *(Detailed Design ..., 2004)*

Nuclide	Volumetric activity, Bq/m^3	
	Maximum values	**Medium values**
^{54}Mn	$1{,}10\times10^{7}$	$7{,}17\times10^{6}$
^{60}Co	$2{,}02\times10^{10}$	$1{,}35\times10^{10}$
^{134}Cs	$6{,}43\times10^{8}$	$3{,}26\times10^{8}$
^{137}Cs	$1{,}80\times10^{10}$	$1{,}63\times10^{10}$
In total	$\mathbf{3{,}89\times10^{10}}$	$\mathbf{3{,}01\times10^{10}}$

Likely the highest (maximum) values of the volumetric activity of the radioactive waste packages is being used to calculate shielding barriers (the thickness of the concrete walls of the final disposal an basements, the thickness of the shielding steel plate of the vehicle, etc.) and to evaluate the possible leak of the radioactive materials during the project-based accidents. The medium value of the volumetric activity of the radioactive waste packages is being used to evaluate the occupational exposure to the workers (including the evaluation of the collective doses) and effective doses for the members of the critical group as well as to arrange the radiological monitoring program.

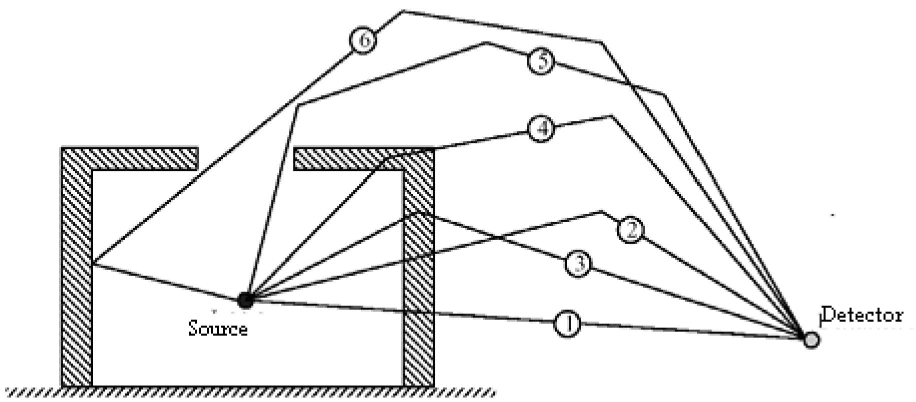
The calculations of the exposure doses show that the radioactive waste package consists of 8 barrels (the volume 200 l) of cemented radioactive waste, which are placed into the radioactive waste cask, cemented in the Ignalina Nuclear Power Plant, and filled with mortar.

The evaluation of the equivalent dose rate

<u>Methods of calculation</u>

The computer programs MERCURE (C.Dupton, 1995) and SKYSHINE (C.M. Lampley et al., 1988) calculate the values of the equivalent dose rate. These programs are used for the calculations of the shielding of the ionising radiation in the tree dimensional space. The programs are examined and legalized comparing calculation results with the standard data of the experimental researches. Moreover, the designed methods of the calculation have been verified by comparing the equivalent dose rates, calculated with these programs, with the simulation results introduced in the project of the cementation devices of the liquid radioactive waste and temporary storage of the Ignalina Nuclear Power Plant, and in the final safety analysis report *(Detailed design ..., 2004)*. In the above-mentioned report, the values of the equivalent dose rate on the surface of the object under investigation and in the particular distance have been counted with the computer program RANKERN. The designed models and calculations of the MERCURE and SKYSHINE computer programs show that the equivalent dose rate calculated by those programs differs in 5% from the results of the RANKERN.

The MERCURE program calculated equivalent dose rates, generated by the ionising gamma radiation, and penetrated through the wall of the cask, transportation cask, temporary storage and final disposal basements, and the SKYSHINE program calculated equivalent dose rates, generated by the radiation, which penetrates through the roofs of the temporary storage and basements. The Picture 4.3.1.1 illustrates the paths of the spread of the ionising radiation, evaluated with the latter program. However, only two ways of the spread are being evaluated when calculating the equivalent dose rate, raised by the radiation, which spreads through the roofs of the temporary storage and basements. These paths are: radiation neutralizes in the wall and disperses in the air as well as radiation disperses in the wall and in the air. In the case of the open basement the further components is being evaluated: the radiation disperses in the air and reflects from the internal wall of the basement as well as radiation disperses in the air.



1) Direct radiation;
2) Radiation neutralized in the wall and dispersed in the air;
3) Radiation dispersed in the wall and neutralized in the air;
4) Radiation dispersed in the air as well as in the wall;
5) Radiation dispersed in the air;
6) The radiation reflected from the wall and dispersed in the air;

Fig. 4.3.1.1 Principle scheme of ionising radiation spread path evaluated with the SKYSHINE program.

The main assumptions for the calculations:

- the calculations of the equivalent dose rate performed in four objects – vehicle (transportation cask), non-shielding casks, one basement and temporary storage;
- the medium values of the individual activity of the cemented radioactive waste packages is such as indicated in the Table 4.3.1.1;
- the casks situated in the periphery of the basement shield the radiation of the internal casks, therefore, while calculating the equivalent dose rate with the MERCURE program , 60 casks, which are near the lateral walls of the basement, were described in the three-dimensional space, and 72 casks, on the surface of the basement, were evaluated while evaluating the influence of the ionising gamma radiation, penetrated through the roof of the basement, with SKYSHINE program;
- in the case of the temporary storage, the radiation, which spreads through the lateral wall of the storage, was evaluated from 10 lateral casks, and the radiation, which spreads through the roof was evaluated from 10 surface casks, because the rest casks is being shielded by the external casks;
- it is defined in the method of the calculation that the thickness of the concrete wall of the basement is 50 cm. The equivalent dose rate, raised by the gamma radiation, which spreads trough the top of the basement, was calculated when the basement was covered with concrete plate (thickness 40cm) as well as when the basement was open;
- it is defined that the thickness of the concrete wall of the temporary storage is 60 cm, and the thickness of the roof is 30 cm;

- the equivalent dose rate has been calculated in the points, distanced from the examined object (non-shielded cask, transportation cask, basement, temporary storage) from 0 to 500 meters;

The repository of the radioactive waste consists of 50 basements. There is an assumption in the simulation that during the exploitation of the repository only one basement is open, and the lateral walls of this open and two closed basements are not filled up with clay and ground. The roofs of the remnant basements are covered with concrete plates and the lateral wall are filled up with clay and ground. In consequence, the total equivalent dose rate, determined by 50 basements, is being calculated by the expression in the particular point:

$S = ANR + (2 \cdot UNR) + (47 \cdot UUR)$,

Here ANR is the equivalent dose rate calculated for the open basement with not filled up walls; URN is dose rate calculated for the closed basement with not filled up walls; UUR is dose rate calculated for the closed basement with filled up walls.

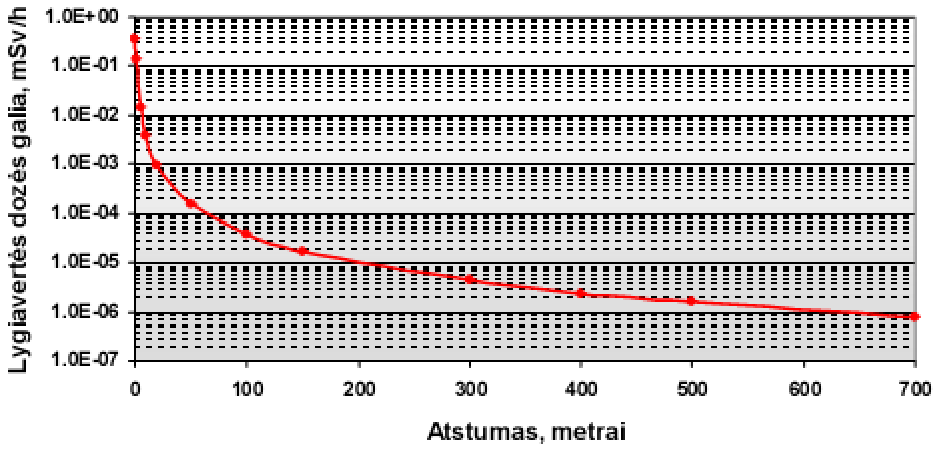
<u>The results</u>

The dependence of the equivalent dose rates on the distance from the examined object is illustrated in the Pictures 4.3.1.2 – 4.3.1.5. The analysis of the indefiniteness of the results was not performed, because the purpose of the EIE (Environmental Impact Assessment) report is to evaluate the principal technical answers and a possible environmental impact. The project-based solutions, applied materials and their features will be detailed when preparing the technical project of the repository. The project based solutions will be specified according to the concrete results of the safety analysis. It is planned that the comprehensive analysis of the uncertainty and sensibility of the tapped in data will be performed in the report of the safety analysis of the surface radioactive waste repository.

The assessment of doses

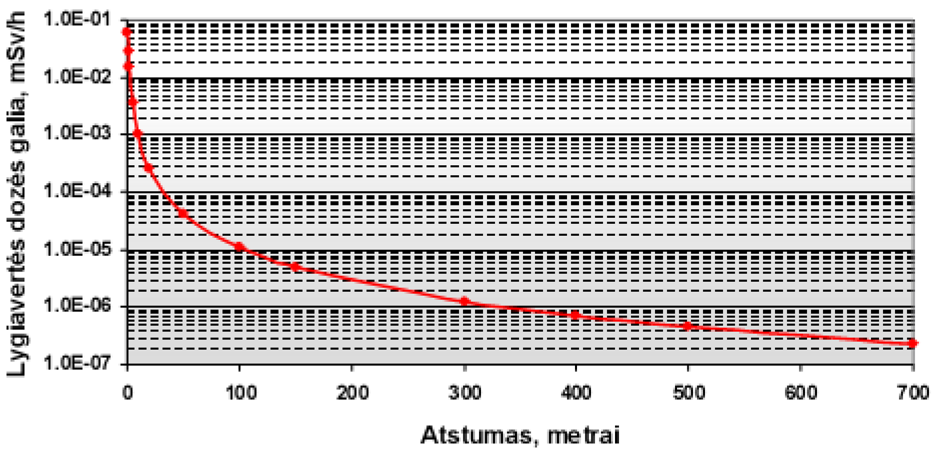
The assessment of the occupational exposure doses can be divided into the assessments of three main components: the assessments of the exposure doses in the normal repository exploitation, during the period of the devices supervision and repairs as well as during the extreme situations.

The threshold effective dose of the workers is 100 mSv per 5 years and the highest annual effective dose is 50 mSv *(Hygiene Standard HN 73-2001, 2002)*. To reduce the doses as much as it is possible, considering economic and social factors, the optimization principles will be applied.



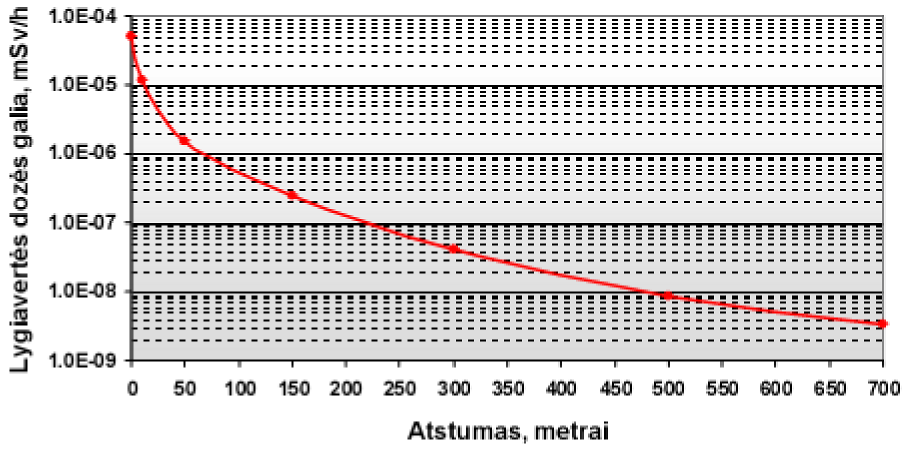
(Vertically – equivalent dose rate mSv/h; *horizontally* – the distance in meters*)*

Fig. 4.3.1.2 Equivalent dose rate dependence on the distance to the non-shielding cask



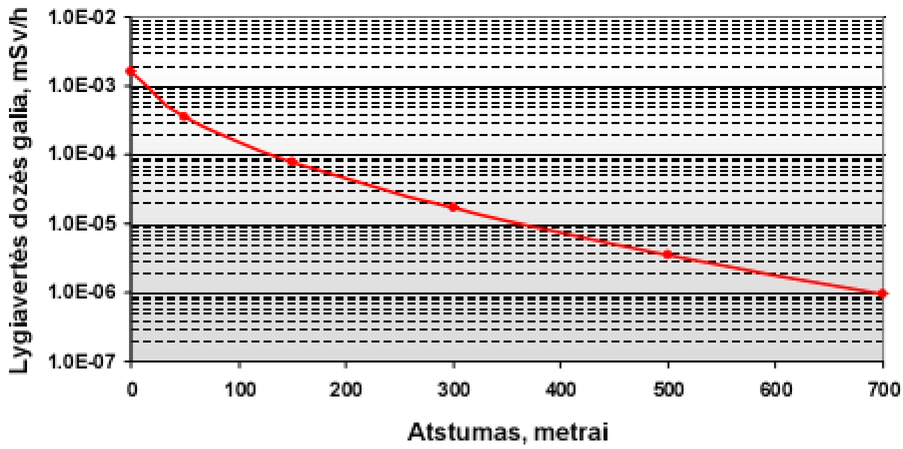
(Vertically – equivalent dose rate mSv/h; *horizontally* – the distance in meters*)*

Fig. 4.3.1.3 Equivalent dose rate dependence on the distance to the transportation cask



(*Vertically* – equivalent dose rate mSv/h; *horizontally* – the distance in meters)

Fig. 4.3.1.4 Equivalent dose rate dependence on the distance to the temporary storage



(*Vertically* – equivalent dose rate mSv/h; *horizontally* – the distance in meters)

Fig. 4.3.1.5 Equivalent dose rate dependence on the distance to the final disposal basements

Normal exploitation

It is planned that 18 thousands radioactive waste packages are going to be buried in the 50 basements of the surface repository in 20 years (50 basements – 360 packages =18000). 900 radioactive waste packages, in the case of normal exploitation, will be brought from Ignalina Nuclear Power Plant to the temporary storage, from the temporary storage they will be brought to the final disposal area and moved to the exploitable basement of the repository per year. The further main activities which determine the doses of the outer occupational exposure in the exploitable repository:

- the transportation of the package from the Ignalina Nuclear Power Plant to the temporary storage of the repository;
- the inspection of the vehicle in the repository;
- the transportation of the package from the temporary storage to the final disposal area;
- the sealing of the covered basement;
- the filling the sidewalls of the covered and sealed basement with the clay material and the compression of that material;
- the formation of the upper coat of the covered basement;
- the construction of the new basements in repository which is already exploitable.

We can see that the list of the occupational exposure does not include such operations as the discharging of the radioactive waste packages, inspection (the surface dose rate, gamma spectroscopy, weight), moving and loading packages in the temporary storage, moving packages from the vehicle and putting them into the section of the basement (in the final disposal area), filling of the well-stocked basements with filler and covering with concrete plates; because all these operations is being performed by the remote control from the central control board which is not in the control area but in the supervisory area. The cameras help an operator to control these operations.

When the conservative assumptions were accepted, it was calculated that the radioactive waste package, which is in the cask, will determine **62 μSv/h** dose rate on the external surface of the transportation cask and **15 μSv/h** dose rate at any point 2 meters from this surface, therefore, it will not come near to the threshold values defined in the Regulations for the Safe Transportation *(Regulations for the Safe ..., 2004; § 508, 572(a), 572(c))*. The dose rate 123 cm from frontal surface of the transportation cask (the driver sits such distance) will be **7.6 μSv/h**. The evaluations of the occupational exposure dose show that the highest dose rate for the driver of the vehicle is 10 μSv/h per hour; the transportation of the package from the Ignaina Nuclear Power Plant to the temporary storage of the surface repository lasts 60 minutes.

When the vehicle with radioactive waste package comes to the surface repository from the INPP, the surface contamination and dose rate of the vehicles are measured with the portable measuring devices of surface contamination and/or in the method of smear to ensure that the Regulations of the Safe transportation are up to standard. These measurements are being performed by the portable devices. However, the dose of the occupational exposure is not big because the package is covered with the shielding barrier (transportation cask) of the vehicle; and the measurements are performed quickly. One measurement of the surface contamination lasts approximately 10 seconds, when the calculated dose rate on the surface of the transportation cask is 62 μSv/h. The calculation of the dose of the external occupational exposure conservatively states that measurements of the surface contamination last 20 seconds when the dose rate is 100 μSv/h. In that case the exposure dose is about 0.56 μSv. The measurement of the dose rate is similar. It is performed by portable telescopic measuring device within 60 seconds when the dose rate is 15 μSv/h. The calculation of the dose of the external occupational exposure conservatively states that measurements of the surface contamination last b0 seconds when the dose rate is 25 μSv/h. In that case the exposure dose is also about 0.56 μSv. It is planned that all the vehicles will be inspected by using 2mSv dose of the external occupational dose per year, because both types of the measurements are applied for one vehicle two times (from both sides of the vehicle).

The evaluations of the doses identify that the radioactive waste packages will be transported in the territory of the repository by the same vehicle, which will be used for the transportation of the radioactive waste packages, cemented in the territory of the Ignalina Nuclear Power Plant. The rate of dose of equal value, in a distance of 123 cm from the frontal surface of the transportation cask (the driver sits in this distance), is 7.6 µSv/h when the thickness of the steel plate, which shields the driver, is 45 mm. The evaluations of the doses of the occupational exposure identify that the rate of the dose of equal value for the driver of the vehicle, which drives in the territory of the repository, is 12 µSv/h, because the driver will be driving in the controlled zone. The rate of the dose of equal value near the well-stocked basements can reach 1.56µSv/h in this zone, when non-shielded cask is not loaded into the exploitable basement. The transportation of the package from the temporary storage to the exploitable basement takes 20 minutes.

It takes one week (5 days – 6 effective working hours is equal to 30 working hours) for four workers to seal up one basement, which is covered with concrete plates. Thus these works will last 75 hours per year. The crane with the temporary roof cannot be shifted over the new basement while the covered basement is not sealed up. Therefore, the new basement is not going to be exploited while these works are in process (the casks will not be loaded into this basement). Thus, the rate of the dose of equal value can reach 1.56µSv/h, however it is conservatively accepted that it will be 2µSv/h.

The filling up of the sidewalls of one basement can take 4 weeks, so these works will take 300 hours per year. The works of the filling up is being performed even when the non-shielded casks are being loaded 900 times per year and each time for 10 minutes in the exploitable basement, which is off 20 meters. Therefore, the rate of the dose of equal value will be 2.51µSv/h only during those 150 hours per year 20 meters in a distance of the exploitable basement. However, the dose evaluations conservatively accept that the rate of the dose of equal value will be 4µSv/h during the whole period of the filling up of the walls.

If the formation of the durable and resistant to erosion upper cover of the basement is performed only at the end of the exploitation of the surface repository, then the rate of the dose of equal value will be very small at that time. The dose evaluations conservatively accept that it will be 1 µSv/h and 10 workers will work all the year round (1500 working hours).

The new basement can be constructed in the exploitable repository. However, considering that a quite number of workers will work in the building lot for a long period of time, and trying to optimize the doses of the external occupational exposure, the construction will be performed at the closest 50 meters from the exploitable basement, where the rate of the dose of equal value may reach 1.71 µSv/h. The dose evaluations contrastively accept that the rate of the dose of equal value will be 2 µSv/h, and 10 workers will work all the year round (1500 working hours).

The table 4.3.1.2 presents the evaluations of the occupational exposure for all the operations. The Table 4.3.1.2 shows us that in the normal situation of the exploitation the values of the individual doses of the occupational exposure are very low, and the collective dose, even in the very conservative evaluation, is only 65 human millisieverts (h-mSv) per year.

Table 4.3.1.2 Operations performed in the repository per year.

Operation	**The number of the workers**	**The number of packages or basements**	**A period per unit**	**The dose rate µSv/h**	**Human-mSv**
The transportation of the package	**2**	**450 packages**	**60 minutes**	**10**	**9**

from INPP to the temporary storage					
The inspection of the vehicle: -the surface contamination; -dose rates.	**1** **1**	**900 packages** **900 packages**	**2x20 seconds** **2x80 seconds**	**100** **25**	**1** **1**
The transportation of the package from the temporary storage to the final disposal area	**1**	**900 packages**	**20 min**	**12**	**3,6**
Sealing of the covered basement	**4**	**2.5 basements**	**30 hours**	**2**	**0,6**
The filling up of the sidewall of the basement	**4**	**2.5 basements**	**120 hours**	**4**	**4,8**
The formation of the upper cover of the basement	**10**	**Repository**	**1500 hours**	**1**	**15**
The construction of the new basements in the exploitable repository	**10**	**Repository**	**1500 hours**	**2**	**30**
Total					**65**

The highest individual values of the doses are for the drivers of the vehicles. If two vehicle carry radioactive waste packages from the Ignalina Nuclear Power Plant to the surface repository and one vehicle carries the packages in the territory of the repository, and if each vehicle is driven by one driver, then the occupational exposure for the driver, who brings the radioactive waste packages from the Ignalina Nuclear Power Plant to the surface repository, will take 450 hours per year. In that case the external occupational exposure of the driver is to be 4.5 μSv/h per year when the rate of the dose of equal value is 10 μSv/h. The dose of the occupational exposure of the driver, working in the territory of the repository, is to be 3.6 mSv/a. This totally meets the requirements of the Lithuanian Legal Acts *(Hygiene Standard HN 73-2001, 2002)* (for the comparison – the intended dose of the occupational exposure for the driver of the vehicle of the radioactive waste, cemented in the Ignalina NPP, transportation is 12 mSv per year *(Detailed design ..., 2004)*).

The workers of the B category will be able to perform the sealing of the covered basement, the filling up of the sidewalls of the basement with the clay based material, and the compression of that material, the formation of the durable and resistant to erosion upper cover of the basement, the construction of the new basements in the exploitable repository and many other operations, because the annual effective dose will not exceed 6 mSc\v.

The maintenance and annual repairs of the devices

The repairs of the overhead crane in the temporary storage of the repository will be performed in the maintenance area of the crane. This area will have to meet the requirements of the station of the third category. The local temporal shielding barriers will be used under the necessities. The evaluations conservatively accept that dose rate is 12 μSv/h.

The maintenance and the annual repairs of the crane of the final disposal area and other devices, moving on the temporary roof is performed when the crane together with the temporary roof drives off of the exploitable basement. However, the evaluations conservatively accept that the rate of the dose of equal value is also 12 μSv/h.

The Table 4.3.1.3 presents the evaluations of the occupational exposure, caused by the maintenance and annual repairs of the devices. The collective effective dose of workers of the surface repository of the radioactive wastes is about 3 human-mSv, i.e. very small dose because of the maintenance and annual repairs of the devices. That is, because simple technologies are used in the surface repository, and it does not have complicated systems or devices. The maintenance and repairs of those technologies may be performed in the environment, where the rate of the dose of equal value is not high.

Table 4.3.1.3 Occupational exposure, caused by the maintenance and annual repairs of the devices

Place	**equipment under repair**	**repair duration, h**	**number of the workers**	**Dose rate**	**Dose, μSv/a**
Temporary storage	crane	20	3	12	720
	Other equipment	10	2	12	240
Final disposal area	crane	30	3	12	1080
	Other equipment	25	2	12	600
Total					**2640**

The observation of the workers

The workers will have to take the accumulating dosimeters (e.g. Class TL) with themselves, when going into the zone, controlled by the surface repository of the radioactive wastes. The drivers of the vehicles will need to wear personal dosimeters (e.g. Class ALNOR-RAD) even outside the controlled area. The indication of the dosimeters will be checked and registered regularly. The workers will be able to see the dose of their expose in the displays of the electronic dosimeters.

When leaving the controlled area, the electronic dosimeters of the workers will be evaluated with the computers, and all the workers will be checked, if there are no radioactive wastes stuck to them. For this reason the devices, identifying the contamination of the surface, will be used. These devices can identify the contamination of the arms, legs, wear and hair.

The individual monitoring of the internal occupational exposure will be performed according to the requirements of the Lithuanian Hygiene Standards HN 12:2001 *(Hygiene Standard HN 112:2001, 2001).*

The exposure of population in the circumstances of the normal exploitation

How it was indicated before, four main sources of the surface repository of the radioactive wastes determine the direct exposure of the population. It was conservatively accepted that the basements of the repository should be well-stocked with radioactive waste packages, possibly the biggest amount of the packages should be stored in the temporary storage, free from any shielding barriers, the radioactive waste package should be hanged on the crane and the vehicle, with the radioactive waste package should drive into the temporary storage. The table 4.3.1.6 schematically shows the influence of the dose rate, caused by these four sources of the ionising radiation, in the controlled area of the surface repository of the radioactive wastes and beyond the fence of the repository.

The territory of the repository will be surrounded by the fence, which is 150 meters outside the basements. The sanitary protection zone (SPZ) around the repository will be defined. The border (border, separating SPZ from other territories) of this territory will be 300 meters outside the repository. The calculations were made for both: for the sanitary protection zone next to the fence of the surface repository of the radioactive wastes, in such place which is in the possibly the closest distance (150 meters) from all four sources of the ionising radiation, and for the territory on the border of the SPZ which is up to 300 meters in a distance from all four sources of the ionising radiation. The calculations conservatively accept that staying in the SPZ should be limited by the annual working hours up to 2000 hours per year; however, people live in 300 meters distance all the time. The well-stocked basements and temporary storages of the repository of the radioactive wastes will affect permanently an inhabitant. The effect of the non-shielded cask, hanging on the crane, will be 150 hours per year (900 casks – 10 min = 9000 min = 150 h); the effect of the driving vehicle will be 300 hours per year (900 casks – 20 min = 18000 min =.300 h).

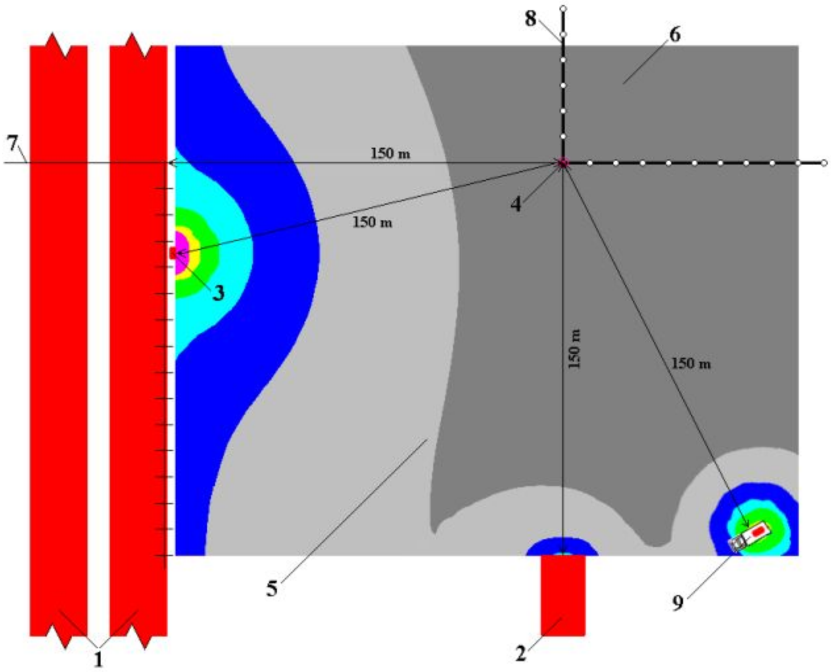


Fig. 4.3.1.6 is the schematic image of the influence of the rate of the dose of equal value in the controlled area of the surface repository of the radioactive wastes, and beyond the repository fence: 1 – well-stocked basements; 2 – temporary storage; 3 – the cask, hanging on the container, and not covered with any shielding barriers; 4 – the repository fence point, which is in possibly the closest distance (150 meters) from all four sources of the ionising radiation; 5 – controlled zone; 6 – territory beyond the repository fence; 7 – the middle axis of the rows of the basements; 8 – repository fence ; 9 – vehicle.

The Table 4.3.1.4 presents the annual dose of the external exposure of population, caused by the impact of all sources of the ionising radiation in the controlled zone of the surface repository of the radioactive wastes. We can see that the annual dose of the exposure of the inhabitant, determined by all sources of the ionising radiation of the surface repository of the radioactive wastes, in the neighbouring territories of the border of the sanitary protection zone, is 0.15 mSv and does not exceed the limited dose value, which is 0.2 mSv *(A Normative Document ..., 2001).* The annual external exposure dose of the inhabitant in the sanitary protection zone near the repository fence (150 meters from the repository basements) is 0.16 mSv and does not exceed the limited dose value.

It should be noticed that annual effective doses of the members of the critical groups of the inhabitants were evaluated when very conservative assumptions were accepted. Firstly, the natural decrease of the activity, in the course of the time, wasn't considered enough, when evaluating the external exposure dose. The real dose will be smaller several times, as the wastes will be buried in 2013 – 2030, and ^{60}Co, which has a half-life of 5 years, is the only important nuclide, determining the external radiation. The dose rate will lower about 4 times during 10 years of the waste storage. Moreover, the dose rate will decrease in the environment, if the construction and sealing works are planned and combined properly, because at the same time there will be 3-4 times smaller number of the unsealed basements in the repository. The shielding barriers can be easily projected and installed, in case there are need to reduce more the intensity of the ionising radiation.

To reduce the rate values of the dose of equal value, some exploitation operations of the repository may be optimized, when preparing the technical project. In that case the border of the sanitary protection zone may be appointed even closer then 300 meters from the repository basements.

The possible means of the reduction of the effect

These means of the reduction of the effect will be applied when preparing the technical project of the repository:

- the proper shielding barriers of the ionising radiation as well as characteristics of those barriers will be designed for the repository basements and temporary storage;
- the remote controlled devices will be applied;
- the radioactive waste packages of different activity will be rationally arranged in the repository basements;
- the sizes of the sanitary protection zone and protected territory of the repository will be properly selected;
- the proper ventilation devices will be projected in the temporary storage;
- the radioactive waste packages is not going to be loaded into new basement, until well-stocked basement is not covered, i.e. until shielding barrier for two components of the ionising radiation are not installed. The components are: radiation dispersed in the air, and radiation reflected from the basement internal wall and dispersed in the air (see Picture 4.3.1.1);
- the engineering barriers of the of the sidewall s of the well-stocked basements will be equipped immediately;
- the special vehicles (transportation casks) will be used to transport the radioactive waste packages;
- the routes of the transportation of the radioactive waste package on the public roads and the period of the transportation of those packages will be optimized.

When it is needed the shielding barriers can be projected and installed.

Table 4.3.1.4 Annual external exposure dose of the inhabitant during the normal exploitation of the repository

	From the well-stocked basements	**From the non-shielded cask**	**From the temporary storage**	**From the vehicle**	**In total**
In the sanitary protection zone near the repository fence (150 meters from the basements)					
The rate of the dose of equal value, mSv per hour	7.87×10^{-5}	1.70×10^{-5}	2.43×10^{-7}	4.8×10^{-6}	-
The duration of the exposure, h	2000	150	2000	300	-
The external exposure dose, mSv per year	0,157	0,0026	0,00049	0,0014	**0,16**

The limits in the neighbouring territories near the sanitary protection zone (300 meters from the basements)					
The rate of the dose of the equal value, mSv per hour	1.68×10^{-5}.	4.40×10^{-6}	4.07×10^{-8}	1.20×10^{-6}	**-**
The duration of the exposure, h	8760	150	8760	300	**-**
The external exposure dose, mSv per year	0.147	0.00066	0.00036	0.00036	**0.15**

The safety of the repository workers will ensure the smaller value of the individual doses, the smaller number of irradiated people than and as low as possible potential of the causeless radiation. For this purpose the optimization program will be performed, when normally exploiting the repository. The coordination working party of the optimization program will be composed in the repository. This group will have to work according to the regulations and realization plan of the optimization program in the repository. The radiation safety means of the repository workers will be defined in the plan. These means should be applied when doing current, planned, maintenance, repairs, inspection and other works. RATA (radioactive Waste Management Agency) will have to report about the implementation of the optimization program works once a year for the Radiation Protection centre and for other commissioned institutions according to their competence *(Hygiene Standard HN 87-2002, 2003)*.

4.3.2. Water

Population exposure during the operation of waste repository

Only hard or hardened radioactive particles the packages of which comply with the criteria for the acceptance of radioactive waste to be disposed in a near-surface repository will be admitted to the repository (*General criteria for radioactive ..., 2003*). The radioactive waste will never be produced at the repository during its operation – a small quantity of liquid radioactive waste (i.e. water from showers, the water that has been used for sanitary cleaning and decontamination both of equipment and vehicles) will be collected and returned back to Ignalina NPP. All the work in the course of which radioactive liquids may be produced will be done at special places, as in accordance with the radioactive safety requirements thereof.

The radioactive waste packages to be disposed, as well as the vaults of the repository, will be reliably secured against rain, and there will be no possibility for radionuclides to get into the rainwater. Nevertheless, the drainage system for rainwater will be installed at the repository under the operation (disposal of radioactive waste). The specific activity of radionuclides in drainage water will be regularly controlled. The measurements are provided for in detail in the monitoring programme (see Chapter 6). During normal operation of the repository, the radionuclides will not get into groundwater, too – therefore, their impact has not been assessed.

Population exposure after the decommissioning of waste repository

It's very important to make sure that people are not affected by radiation due to radionuclides being transferred with water flows in a long run. The analysis of radionuclides transport by groundwater flows has been given in this chapter. Roland Pusch in his assessment of the quality of engineering barriers (*Selection of ..., 2005, Appendix G*) has shown that the selected barriers are very reliable, and water will penetrate into the vaults of the repository not sooner than after several hundred years (approximately 300 years). Therefore, the transfer of radionuclides by water from the repository into environment is secure not to occur during about 300 years. Nevertheless, in order to compare the sites under the discussion with each other and to demonstrate the importance of a natural barrier, an assessment has been done, with conservative supposition that the waste repository vaults are already full of humidity at the time of its decommissioning, and the radionuclides begin to be transported soon after the decommissioning takes place. So, the supposition about the engineering barriers functioning in an ineffective way has been made. This presumption enables us to evaluate both the hydrogeological and hydrological conditions and to compare them between each other in view of possible migration of the radionuclides.

THE SITES OF APVARDAI AND GALILAUKĖ

Concept of the environmental impact assessment

Radionuclides migration through water flow and potential exposure of population has been assessed by using the ISAM methods for the safety assessment of a near-surface repository for radioactive waste, prepared by International Atomic Energy Agency (IAEA) (*IAEA. Safety Assessment..., 2004*). The methods cover the following steps of safety assessment (see Picture 4.3.2.1):

1. *Safety assessment task formulation* – safety analysis scope, safety criteria, specific periods of time and other parameters of a specific safety assessment task are

defined;

2. *Radioactive waste disposal system description* – the system under analysis, including radioactive waste and its packages, engineering barriers, ways of radionuclides migration both in geosphere and biosphere, together with specification of their features, is described. The system is described based on formulated safety assessment task;

3. *Creation and substantiation of scenarios for radionuclides migration in the environment* – the analysis of processes, which take place in the repository, geosphere and biosphere, is made, and scenarios as well as conceptual models are created;

4. *Composition of mathematical models* – conceptual models in a form of mathematical dependencies are formulated, and initial as well as limiting simulation conditions are defined;

5. *Calculations* – the calculations are done with the help of a software or by using either analytical or numerical methods;

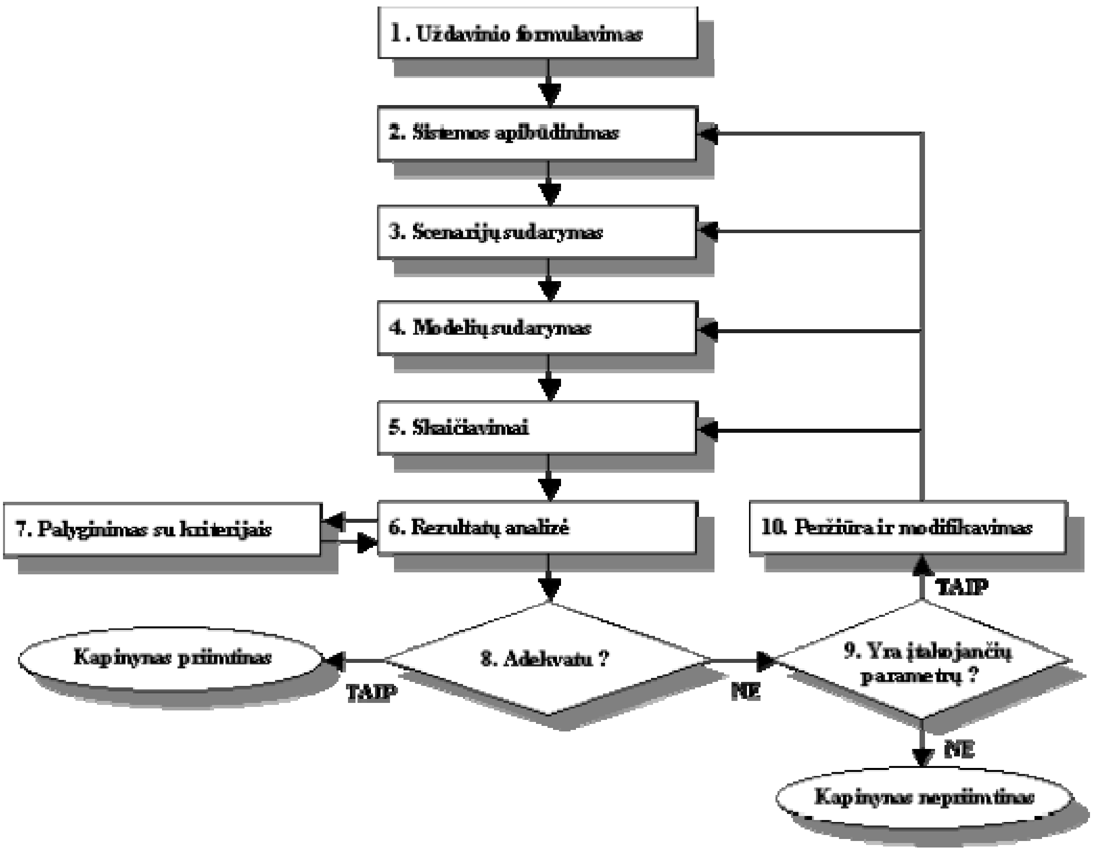
6. *Results analysis* – the results of calculations are analyzed;

7. *Collation with criteria* – results of calculations are collated with task-defined safety criteria;

8. *Safety assessment adequacy determining* – it is determined, whether the criteria are fulfilled. If no, steps 9 and 10 are executed.

9. *The determining and fine-tuning of parameters that influence safety assessment*;

10. *Safety assessment components review and modification.*



(Uždavinio formulavimas – task formulation;
Sistemos apibūdinimas – system characterization;
Scenarijų sudarymas – creation of scenarios;
Modelių sudarymas – creation of modules;

Skaičiavimai – calculations;
Palyginimas su kriterijais – Collation with criteria;
Rezultatų analizė – Analysis of results;
Peržiūra ir modifikavimas – Review and modification;
Kapinynas priimtinas – the repository is acceptable;
Adekvatu? – is it adequate?
Yra įtakojančių parametrų? – Are there influencing parameters?
Kapinynas nepriimtinas – the repository is not acceptable;
)
Picture 4.3.2.1. Diagram for application of ISAM methods.

The above mentioned methods have been used to assess both the possible migration of radionuclides from the near-surface waste repository by way of water flows and impact that the ionizing radiation have upon environmental components (biota).

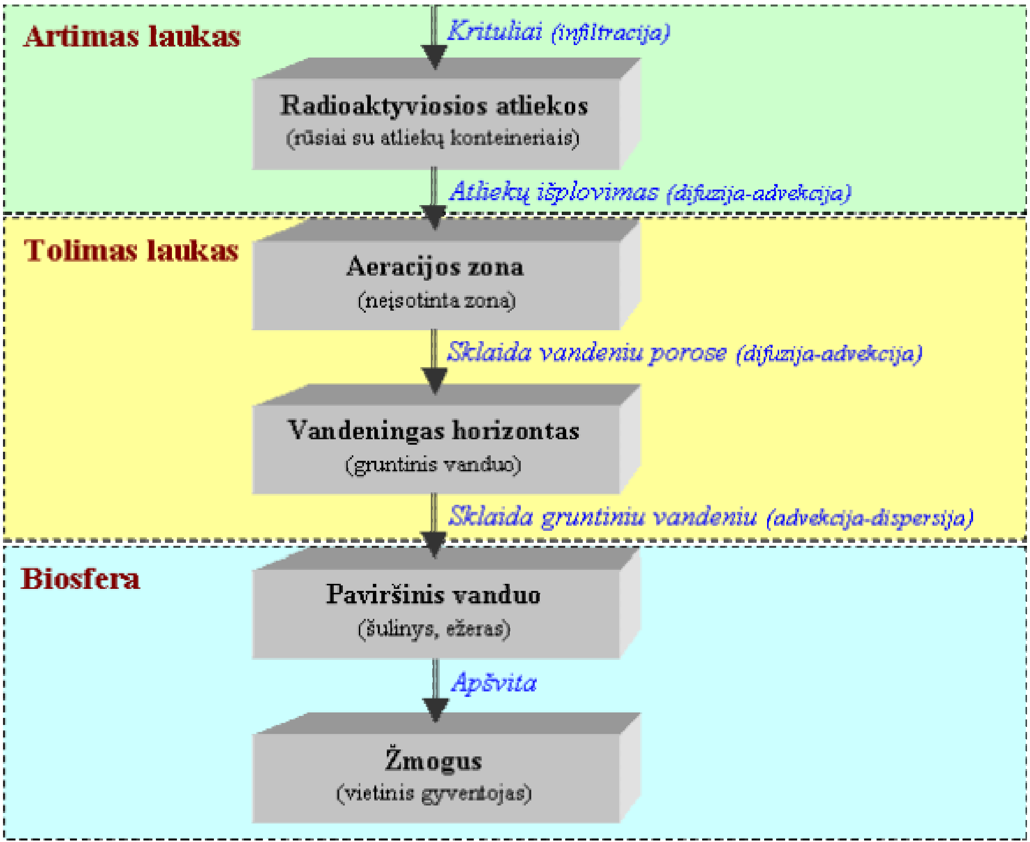
Safety assessment task formulation

The scope of the analysis given in this chapter of PAV report is to assess both the radionuclides migration and an impact that the radiation thereof have on the population. The analysis is made by taking into account the properties of radioactive waste to be disposed of , the structural concept of a near-surface repository and both the geological and hydrogeological specifics of the sites of Galilaukė and Apvardai, which are selected for the construction of this repository.

Radiation safety criterion is an annual effective exposure dose gained by the member of a critical population group. The annual effective radiation dose gained by the member of a critical population group for a near-surface waste repository to be built must not surpass dose constraint applicable for nuclear installations, which are planned to be constructed, and is equal to 0,2 mSv per annum (*Hygiene norm HN 87:2002, 2003*). The period of time of the repository development, including both its active and passive institutional surveillance, as well as a later period, during which the possibility of long-lived radionuclides getting into the environment exists, concerning radionuclides migration and impact on the environment, has been analyzed. In calculations, it has been supposed that an active surveillance period is 100 years and the one of passive surveillance – 200 years. During active surveillance period, a physical safety will be ensured, the monitoring of the environment will be performed, the work for barriers maintenance will be done and, if needed, corrective measures will be taken. During the next, passive, surveillance period, after the end of that of active surveillance, the use of land in the territory of the repository will be limited, and restrictions on some type of the activities will be applied (*Small and Medium ..., 2002*).

Radioactive waste disposal system description

Radionuclides migration from the near-surface waste repository by water flows can be initiated by precipitation. Radionuclides washed off from nuclear waste package by infiltrated water can penetrate by way of advectional and diffusion transfer through the bottom of engineering barriers of a vault and get into aeration zone that is located beneath them. The water that fills the pores of aeration zone can transfer radionuclides into the deep-lying layer of groundwater table (aquifer). Further, through aquifer, the radionuclides can spread to biosphere and result in external, as well as internal, exposure of population. In the assessment of radionuclides migration, three zones of radionuclides transfer are discerned: the near field that encompasses the repository, all the radioactive waste that is deposited in it, and engineering barriers, which surround all the vaults of the repository, the remote field, which comprises aeration zone and aquifer, and biosphere with all near-surface waters, flora, fauna and humans. In this work, the common scheme for analyzed zones, processes and their interrelations is given in Picture 4.3.2.2.



(Artimas laukas – near field

Krituliai (infiltracija) – precipitation (infiltration);

Radioaktyviosios atliekos (rūsiai su atliekų konteineriais) – radioactive waste (vaults with deposited waste casks);

Atliekų išplovimas (difuzija ir advekcija) – washing-away of waste (diffusion and advection);

Tolimas laukas – remote field;

Aeracijos zona (neįsotinta zona) – aeration zone (insatiated zone);

Sklaida vandeniu porose (difuzija ir advekcija) – migration by water in pores (diffusion and advection);

Vandeningas horizontas (gruntinis vanduo) – aquifer (groundwater);

Sklaida gruntiniu vandeniu (difuzija ir advekcija) – migration by groundwater (diffusion and advection);

Biosfera – biosphere;

Paviršinis vanduo (šulinys, ežeras) – surface water (well, lake);

Apšvita – exposure;

Žmogus (vietinis gyventojas) – a person (from local population)

)

Picture 4.3.2.2. Common scheme for radionuclide migration components and processes.

Description of radioactive waste to be disposed of in the near-surface repository is given in Chapter 2. The list of radionuclides comprising the waste, together with specific activity values of concrete matrix (cask of 0.2 m^3 capacity), is given in Table 2.1.1 of Chapter 2. In addition, the list of radionuclides assessed in calculations for radionuclides migration by water, in which all the radionuclides are grouped according to their physical (half-life) and chemical (sorption coefficient) properties, is given in Table 4.3.2.1. It is necessary to note that when doing calculations for ionizing radiation the short-lived radionuclides ^{60}Co, ^{134}Cs and ^{54}Mn have not been taken into account because they do not influence the environmental impact assessment results.

The possible radionuclides migration from the repository depends on the properties of engineering barriers. The scheme for engineering barriers and processes causing radionuclides migration, drawn up according to the design concept of the near-surface repository, which is given in Chapter 2, is shown in Picture 4.3.2.3. The summary of specifications of engineering barriers of vaults that have been assessed in the radionuclides migration analysis, which has been made in accordance with the data presented in document (*Reference Design ..., 2002*), is given in Table 4.3.2.2.

Table 4.3.2.1. Radionuclides and their parameters.

Grupė		Radio-nuklidas	Pusėjimo trukmė, metai	Sorbcijos koeficientas (K_d) zonoje/medžiagoje, m^3/kg				
				Sucementuotos radioaktyviosios atliekos *	Betonas *	Pagrindas (smėlio-žvyro-žvirgždo mišinys)*	Aeracijos zona (priemolis) **	Vandeningas horizontas (smėlis) **
Trumpa-amžiai	Silpnai sorbuo-Jami	^{3}H	12,3	0	0	0	0	0
		^{90}Sr	28,8	0,001	0,001	1×10^{-4}	0,02	0,013
	Stipriai sorbuo-jami	^{137}Cs	30,1	0,001	0,001	0,01	4,4	0,27
		^{241}Pu	14,4	5	5	1	1,2	0,54
Ilga-amžiai	Silpnai sorbuo-jami	^{14}C	5 730	0,2	0,2	0,002	0,002	0,005
		^{129}I	$1,57\times10^{7}$	0,003	0,003	0	$4,5\times10^{-3}$	0,001
		^{59}Ni	8×10^{4}	0,04	0,04	0,01	0,3	0,4
		^{63}Ni	100	0,04	0,04	0,01	0,3	0,4
	Stipriai sorbuo-jami	^{94}Nb	$2,03\times10^{4}$	0,5	0,5	0,5	0,54	0,16
		^{99}Tc	$2,11\times10^{5}$	0,5	0,5	0,3	1×10^{-4}	$1,4\times10^{-4}$
		^{241}Am	432	1	1	1	0,99	2
		^{234}U	$2,46\times10^{5}$	5	5	1	0,012	0,033
		^{235}U	$7,04\times10^{8}$	5	5	1	0,012	0,033
		^{238}U	$4,47\times10^{9}$	5	5	1	0,012	0,033
		^{237}Np	$2,14\times10^{6}$	5	5	1	0,025	$4,1\times10^{-3}$
		^{238}Pu	87,7	5	5	1	1,2	0,54
		^{239}Pu	$2,41\times10^{4}$	5	5	1	1,2	0,54
		^{240}Pu	$6,56\times10^{3}$	5	5	10	1,2	0,54

*

Table 4.3.2.1. Radionuclides and their parameters.

Group		Radio-nuclide	Half-life, years	Sorption coefficient (K_4) in zone/material, m^3/kg				
				Cemented radio-active waste*	**Concrete***	**Foundation (sand-gravel-rough sand mixture)**	**Aeration zone (loam)****	**Aquifer (sand)****
Short-lived	Weakly sorbing	H 3	12,3	0	0	0	0	0
		Sr 90	28,8	0,001	0,001	1×10^{-4}	0,02	0,013
	Strongly Sorbing	Cs 137	30,1	0,001	0,001	0,01	4,4	0,27
		Pu 241	14,4	5	5	1	1,2	0,54
Long-lived	Weakly sorbing	C 14	5730	0,2	0,2	0,002	0,002	0,005
		I 129	$1{,}57 \times 10^{7}$	0,003	0,003	0	$4{,}5 \times 10^{-3}$	0,001
		Ni 59	8×10^{4}	0,04	0,04	0,01	0,3	0,4
		Ni 63	100	0,04	0,04	0,01	0,3	0,4
	Strongly Sorbing	Nb 94	$2{,}03 \times 10^{4}$	0,5	0,5	0,5	0,54	0,16
		Tc 99	$2{,}11 \times 10^{5}$	0,5	0,5	0,3	1×10^{-4}	$1{,}4 \times 10^{-4}$
		Am 241	432	1	1	1	0,99	2
		U 234	$2{,}46 \times 10^{5}$	5	5	1	0,012	0,033
		U 235	$7{,}04 \times 10^{8}$	5	5	1	0,012	0,033
		U 238	$4{,}47 \times 10^{9}$	5	5	1	0,012	0,033
		Np 237	$2{,}14 \times 10^{6}$	5	5	1	0,025	$4{,}1 \times 10^{-3}$
		Pu 238	87,7	5	5	1	1,2	0,54
		Pu 239	$2{,}41 \times 10^{4}$	5	5	1	1,2	0,54
		Pu 240	$6{,}56 \times 10^{3}$	5	5	10	1,2	0,54

* the values have been taken from (*Project SAFE, ...2001*);
** the values have been taken from (*IAEA. Handbook ..., 1994*).

The summary of aeration zone specifications that have been assessed in the radionuclides migration analysis, which has been made in accordance with geological and hydrogeological conditions of the sites, which are described in Section 4.1, is given in Table 4.3.2.3. The summary of aquifer specifications that have been assessed in the radionuclides migration analysis, which has been made in accordance with geological and hydrogeological conditions of the sites, the description of which are given in Section 4.1, is given in Table 4.3.2.4.

Infiltration

Diffusion

Sand layer
Clay based material layer
Sand layer
Reinforced concrete cover
Radioactive waste
Reinforced concrete bottom
Foundation

Advection

Picture 4.3.2.3. Concept of engineering barriers of the vault and radionuclide migration processes.

Table 4.3.2.2. Repository vault's engineering barriers parameters.

Barrier	**Material**	**Thick-ness, m**	**Dry material density, kg/m^3**	**Poro-sity**	**Filtration coefficient, m/s**		**Coefficient of effective diffusion, cm^2/s**
					When barrier is not degraded	**When barrier is degraded**	
Sand layer	Sand	0,5	-	-	-	-	-
Clay based material layer	Smectic clay	1,5	2000	0,25	1×10^{-10}	1×10^{-8}	1×10^{-6}
Sand layer	Sand	0,2	-	-	-	-	-
Reinforced concrete lid	Concrete	0,4	2300	0,15	1×10^{-9}	1×10^{-8}	1×10^{-7}
Radioactive waste	Cement matrix	6,5	2000*	0,25*	1×10^{-9}	1×10^{-8}	1×10^{-6}
Reinforced concrete bottom	Concrete	0,6	2300	0,15	1×10^{-9}	1×10^{-8}	1×10^{-7}
Foundation	Sand-gravel-rough sand mixture	1,0	2000	0,40	5×10^{-7}	-	8×10^{-6}

* values have been chosen for cemented waste

The ways of radionuclide migration in geosphere at the site offered for the construction of the repository are described in Section 4.1. The pathways for population exposure, which causes maximum doses of irradiation, are the following: 1) for the sites of Galilaukė and Apvardai – water in the well drilled near the repository (well that reaches the groundwater table) and 2) for the site of Apvardai – water of Apvardai lake (the place for discharging the groundwater that transports radionuclides escaped from the repository). The main parameters of biosphere are given in Table 4.3.2.5.

Table 4.3.2.3. Aeration zone parameters for the sites offered as a construction site for the repository.

Site name	Material	Thickness, m	Dry material density, kg/m^3	Porosity	Filtration coefficient, m/s	Effective diffusion coefficient, cm^2/s
Galilaukė	Clay loam	30	1950	0,25	1 x 10^{-7}	1 x 10^{-6}
Apvardai	Clay loam	3,5	1950	0,25	1 x 10^{-7}	1 x 10^{-6}

Table 4.3.2.4. Groundwater table parameters for the sites offered as a construction site for the repository.

Site name	Material prevalent in the ground-water table	Thickness, m	Dry material density, kg/m^3	Porosity	Water flow, m/year	Dispersion coefficient, m		
						In the direction of flow towards the well, 150 m away	In the transversial direction towards the well, 150 m away	In the direction of flow towards the lake, 1300 m away
Galilaukė	Sand	10	1900	0,3	6,31	15	-	-
Apvardai	Sand	2,2	1900	0,3	2,21	15	1,5*	130

* When analyzing the barrier degradation scenario, the assessment for radionuclide ^{14}C has been made, assuming that irradiation pathway – well.

Creation and substantiation of scenarios for radionuclide migration in the environment

The scenarios can be created and picked out of those that are available in several ways (*IAEA. Safety Assessment…, 2004*): *a)* by analyzing the list of important processes and events, which can influence a near-surface repository evolution, *b)* by using general scenarios created and analyzed for the likes of near-surface depositories or *c)* by applying a formalized procedure. In this report for the assessment of the impact the scenarios have been selected by applying a formalized procedure that consists of four main steps:

1. The radioactive waste disposal system under consideration is divided into main components;
2. Characteristic states of the components are defined;
3. The combinations of these states, together with scenarios based on them, are composed;
4. The scenarios are generalized and grouped together.

For the assessment of radionuclides migration impact three radionuclides transfer components (zones) have been singled out (see Picture 4.3.2.2): (i) near field, (ii) remote field (geosphere), and (iii) biosphere.

The near field, which encompasses radioactive waste and engineering barriers, can be in the following states:

- *stationary*: i.e. when engineering barriers retain their design properties. In this case, water will not penetrate into the repository or there will be only a minimum water flow depending both on the repository structure and engineering barriers properties;
- *naturally degraded*: the engineering barriers do not limit water flow into the repository; the influence of the flow depends on the natural conditions i.e. the amount of precipitation getting into the repository.

Table 4.3.2.5. Biosphere main parameters

Name of parameter	**Value**
Apvardai lake average depth of Apvardai lake, m	2,65
Apvardai lake area, ha	550,2
Apvardai lake sediment upper layer thickness, m	0,02
Apvardai lake capacity, % per annum	218
Root crop, kg/m^2	0,5
Leaf-bearing vegetables harvest, kg/m^2	0,7
Consumption of meat per capita, kg/year	95
Consumption of dairy products per capita, litres/year	940
Consumption of root vegetables per capita, kg/year	66
Consumption of green leafy vegetables per capita, kg/year	18
Consumption of fish per capita, kg/year	11
Consumption of water per capita, litres/year	600
Time spent on contaminated soil, hours/year	50
Inhalation rate, m^3/hour	1
Watered field (of kitchen-garden) area, m^2	200
Soil upper layer depth, m	0,25
Both upper and lower layer depth, m	1
Quantity of removed soil, kg/m2 per year	0,005
Dairy cattle animals number	4
Meat cattle animals number	4
Water consumption by dairy cattle, litres/day	70
Water consumption by meat cattle, litres/day	40
Water plant consumption by dairy cattle, kg/day	1
Water plant consumption by meat cattle, kg/day	1

In this assessment, it was supposed that the state of repository remains unchanged for the first 100 years after its decommissioning during the active institutional surveillance period of the repository, in the course of which maintenance work is done, if needed. It has been assumed that the repository enters the state of naturally degraded repository during its passive surveillance period (100 to 300 years after decommissioning of the repository). The concrete barriers placed under the repository heap begin to deteriorate and uniformly degrade. The limitations that are put on all sorts of activities in the territory of the repository for the passive surveillance period of the repository are enough to ensure that the heap is kept intact with all the design properties being unchanged during this period. The significance of water flows going through the repository depends on the state of partly degraded concrete barriers as well as design hydraulic conductivity of clay barriers. At the end of institutional surveillance period (300 years after decommissioning of the repository) the engineering barriers of the repository can be in two states: either of natural degradation or total degradation. During this period, totally degraded concrete barriers, together with those of natural material (clay) having retained their design properties, are inherent to the state of natural degradation. When assessing the state of totally degraded concrete barriers after the institutional surveillance period, the possibility that unforeseen natural phenomena or human activity can cause the engineering barriers being destroyed in full earlier than when there are only natural processes, has been taken into account.

Based on the defined states two scenarios for the evolution of engineering barriers of the repository have been created – the more probable one of *natural development* and the conservative one of *degradation of engineering barriers* (see Table 4.3.2.6). The values of water flow through the repository for all the states of engineering barriers have been assessed according to the methods given in the report (*Reference Design ..., 2002*).

Table 4.3.2.6. Repository engineering barriers states and engineering barriers development scenarios.

Period of institutional surveillance	**Repository engineering barriers development scenarios**			
	Natural development		**Degradation of engineering barriers**	
	The state of engineering barriers	**Water flow through repository, m per year**	**The state of engineering barriers**	**Water flow through repository, m per year**
Active (up to 100 years)	Unchanged	0.015	Unchanged	0.015
Passive (from 100 to 300 years)	Naturally degraded	0.015 – 0.021	Naturally degraded	0.015 – 0.021
No surveillance (over 300 years)	Naturally degraded	0.021	Totally degraded	0.200

In this analysis, the near field (geosphere) and biosphere components are considered to be stable throughout the repository evolution. These components have no alternative states attached to them; therefore, feasible evolution scenarios for these components are not created. The scenarios of feasible radionuclides migration by means of water transfer are determined by repository engineering barriers development scenarios. The repository engineering barriers development scenarios, together with unchangeable geosphere and biosphere components, make scenarios for repository normal development as well as those for repository engineering barriers degradation.

Mathematical models

The radionuclide migration in both the repository and aeration zone has been calculated by solving diffusion equation and considering hydrodynamic dispersion and radioactive decay processes. The software DUST (*Sullivan T. M. ..., 1993*) has been used for the solving of equation. The equation is solved by using finite differences method by dividing the vertical cross-section of repository vault and aeration zone into equal cells/compartments of equal height of 10 cm.

Precipitation infiltration through repository barriers and dynamics of repository flooding by water (satiation) has not been considered. The conservative assumption that, after the repository decommissioning, radioactive waste packages and filling material pores are fully filled with water has been made. The waste matrix that is made of immobilized (cemented) waste located in a near-surface repository is an important engineering barrier the physical and chemical properties of which determine how radionuclides are exuded into environment. In the radionuclides migration analysis, the radionuclides penetration out of waste matrix hasn't been simulated. Instead of it, an assumption that radionuclides both are fully solved in the water of surrounding material pores and uniformly distributed in vault, has been made, thus, by considering in such a way all technologies of possible waste processing. It has been assumed that there's a stationary balance in concentration between radionuclides in liquid state (water) and solid state (absorbing material). The amount of moisture, effective diffusion coefficient and hydrodynamic dispersion coefficient (see Table 4.3.2.2) have been considered as being constants. The physical and chemical processes that limit radionuclides solubility have not been taken into account, as well. In addition, in the calculations the activity of radionuclides has been considered to be such as it would be in the beginning of the nuclear waste repository operation and not in the beginning of institutional surveillance thereof, because it is not known exactly by what amounts and at what stages the waste is going to be deposited in the repository after its construction has been completed. Due to all the above-mentioned and used-in-calculations assumptions, the results of radionuclide migration from the repository should be considered as being conservative ones (the migration is exaggerated).

The exaggeration of radionuclides migration (overestimated value) causes an environmental impact (external dose), in comparison to the real one, to be exaggerated, as well.

The radionuclide migration in aquifer has been calculated by solving one-dimensional advection equation by considering hydrodynamic dispersion and radioactive decay processes. The software package GWSCREEN (*Rood A. S. ..., 2003*) has been used for the solving of equation. In most cases a one-dimensional (longitudinal) dispersion has only been considered, so the calculations of radionuclide migration in aquifer should be considered as being conservative ones (the migration is exaggerated). The exaggeration of radionuclides migration makes a feasible environmental impact (ionizing radiation exposure) to be exaggerated (overestimated), as well.

To assess the possible exposure of population, that could be gained by consuming water from a well (borehole to the aquifer), the dose, which the population could be exposed to if the well is drilled next to the fence of the near-surface waste repository, has been calculated. The size of to-be-established sanitary protection zone and the limitation of possible human activities in it have not been considered. It has been assumed that the radionuclides having had penetrated from a single vault migrate to the well that is installed 150 m away from the vaults of the repository. The average water consumption per capita – 0.6 m^3 (600 litres) per annum.

The potential population exposure, which people could be exposed to in case radionuclides get into the lake Apvardai, has been analyzed with the help of software AMBER (*Scientific Software ..., 2002*). This software solves linear differential equation that simulates radionuclides mass transfer processes among analyzed system (in this case, lake) components. The conceptual model for the radionuclide migration in a lake (see Picture 4.3.2.4) has been based on the work (*S. Karlsson ..., 2001, U. Bergström ..., 1999, U. Bergström ..., 2004*). The description of transfer coefficients among separate parts of the system and from the system is given in the Table 4.3.2.7. The expressions of coefficients are given in the papers (*S. Karlsson ..., 2001, U. Bergström ..., 1999, U. Bergström ..., 2004*).

The possible exposure of population has also been calculated by means of the software AMBER. The parameters needed for the calculation of doses, together with their values, are presented in the papers (*S. Karlsson ..., 2001, U. Bergström ..., 1999, U. Bergström ..., 2004, V. Filistovič ..., 1998, T. Nedveckaitė ..., 2000*), and some of them are given in the Table 4.3.2.5. The most of parameters are general ones and only some of them reflect local conditions. The overall annual effective dosis of a local inhabitant has been assessed (see Picture 4.3.2.5), this consisting of:

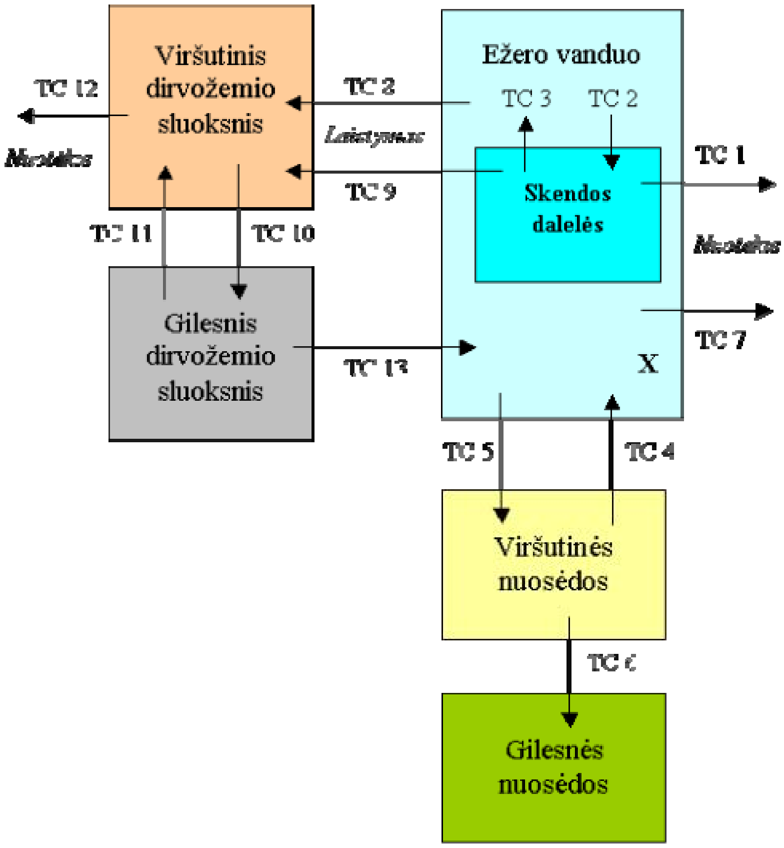
External exposure, caused by contaminated site;

Internal exposure, caused by these factors: inhaled dust of contaminated soil (during work at kitchen-garden), drinking of water from the lake; consumption of meat and milk from the cattle that graze on the cost of lake, consumption of vegetables being watered by the lake water and consumption of fish caught in the lake.

All the software packages that have been used for the calculations – DUST, GWSCREEN and AMBER were used in ISAM project for the solution of a near-surface repository security analysis test tasks and are present (with exclusion of GWSCREEN) in the list of software recommended by IAEA for the sort of analyses (*IAEA. Safety Assessment…, 2004*). The information on the verification of the model having been used for the assessment of biosphere is given in the work (*U. Bergström ..., 1999*).

Results of calculations based on the scenario for the normal repository development

After the analysis of 18 radionuclides migration in the territory of the repository, as well as biosphere, had been made, it has been established that only 12 of them would reach the biosphere by the groundwater flow. The short-lived weakly sorbing ^{90}Sr radionuclide, the short-lived strongly sorbing ^{137}Cs and ^{241}Pu radionuclides, and long-lived ^{63}Ni, ^{241}Am and ^{238}Pu radionuclides would not reach the groundwater discharge points. The effective doses have been only assessed for those 12 radionuclides that have reached the biosphere: short-lived ^{3}H and long-lived ^{14}C, ^{129}I, ^{59}Ni, ^{94}Nb, ^{99}Tc, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu and ^{240}Pu radionuclides.



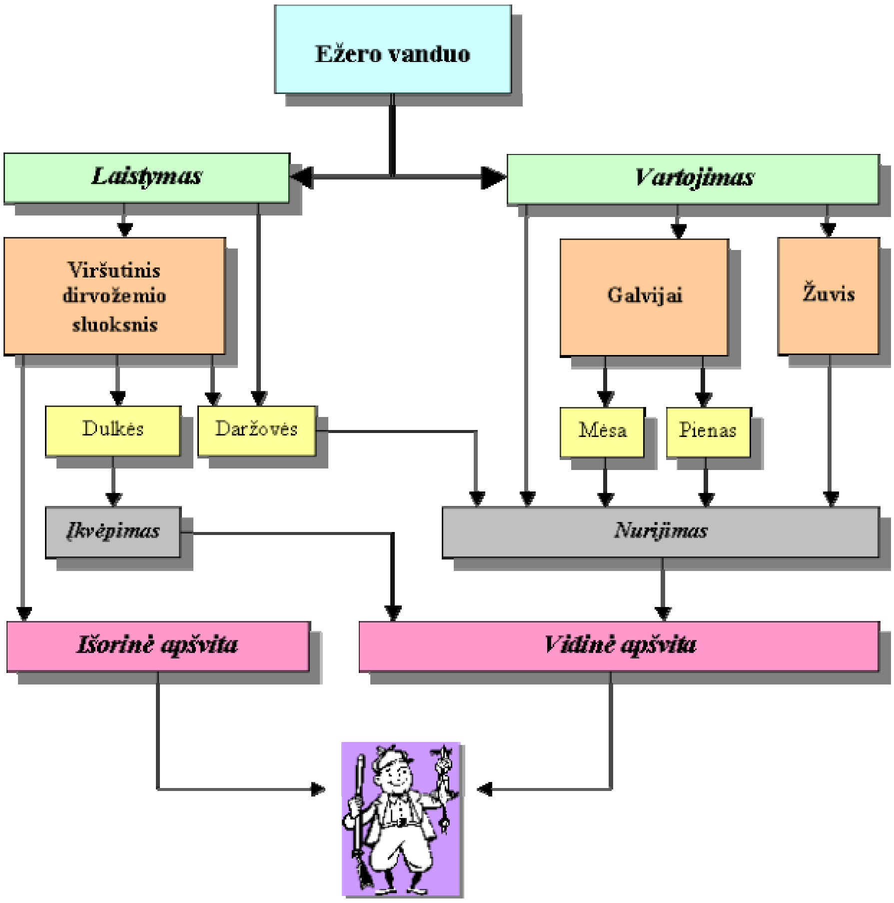
Picture 4.3.2.4. Conceptual lake model. X signifies the beginning of radionuclide migration to the lake by groundwater flows.

(Picture 4.3.2.4:
Nuotekos – waste water
Viršutinis dirvožemio sluoksnis – upper layer of the soil
Laistymas – watering
Ežero vanduo – lake water
Skendos dalelės – suspended matter
Gilesnis dirvožemio sluoksnis – deeper layer of the soil
Viršutinės nuosėdos – upper sediment
Gilesnės nuosėdos – deeper sediment
)

Table 4.3.2.7. Transport coefficients for the lake model.

Coefficient	Description
TC1	Decrease in radionuclides quantity due to the fluctuation of suspended matter together with lake water.
TC2	Radionuclide sorption in the suspended matter of the lake.
TC3	Radionuclide desorption from the suspended matter of the lake.
TC4	Radionuclide transport from the upper sediments layer back to the suspended matter.
TC5	Radionuclides sedimentation, together with the suspended matter, on the bottom of the lake.
TC6	Radionuclides transport from the upper sediments layer to the deeper sediments.

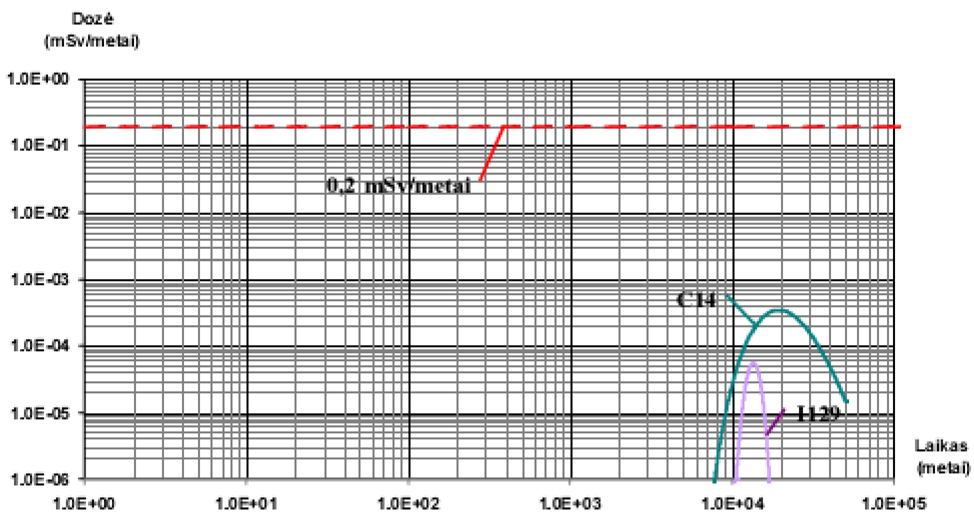
TC7	Decrease in radionuclides quantity due to mixing of lake water.
TC8	Radionuclide transport to vegetables and the upper layer of a soil by watering kitchen-garden with lake water.
TC9	Radionuclide transport from suspended matter to vegetables and the upper layer of a soil by watering kitchen-garden with lake water.
TC10	Radionuclide transport from the upper layer of a soil to the deeper layers of it, caused both by watering of kitchen-garden and bioorganisms' activity.
TC11	Radionuclide transport from the bottom layer of a soil to the upper one caused by bioorganisms' activity.
TC12	Removal of radionuclides from the system because of erosion (soil removal).
TC13	Radionuclide transport from the bottom layer of a soil back to the lake water.



Picture 4.3.2.5. Exposure pathways considered in the model for lake.
(
Ežero vanduo – lake water
Laistymas – watering
Vartojimas – usage
Viršutinis dirvožemio sluoksnis – the upper layer of a soil
Galvijai – cattle
Žuvis – fish
Dulkės – dust

Daržovės – vegetables
Mėsa – meat
Pienas – milk
Įkvėpimas – inhalation
Nurijimas – swallowing
Išorinė apšvita – external exposure
Vidinė apšvita – internal exposure
)

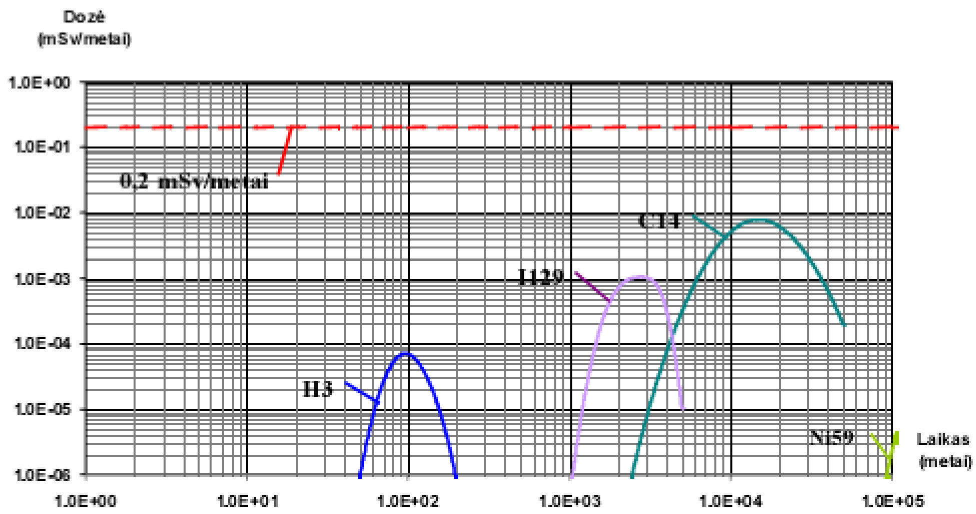
Time dependence of effective doses caused by radionuclide migration for the site of Galilaukė, where the supposed exposure pathway is the well drilled near the repository (150 metres away from the vaults), is given in Picture 4.3.2.6. As it can be seen from the results, potentially the highest exposure could be caused by ^{14}C radionuclide. The maximum exposure is expected in the period of 9-10 thousand years after the decommissioning of the repository and would be of insignificant value (lower by two orders) in comparison with annual dose constraint equal to 0.2 mSv. The exposure caused by other radionuclides is even less.



(
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.6. Effective doses (depending on time), caused by radionuclides migration for the site of Galilaukė according to natural development scenario when contaminated groundwater gets into the well drilled near the repository, and their comparison with the annual dose constraint of 0.2 mSv.

Time dependences of assessed effective doses caused by radionuclides for the site of Apvardai when exposure pathways are the well drilled 150 m away from the repository and Apvardai lake, which is situated at a distance of 1300 m from the repository, are given in Picture 4.3.2.7 and 4.3.2.8. In this case, again, the potential exposure is by two-three orders lower than dose limit.



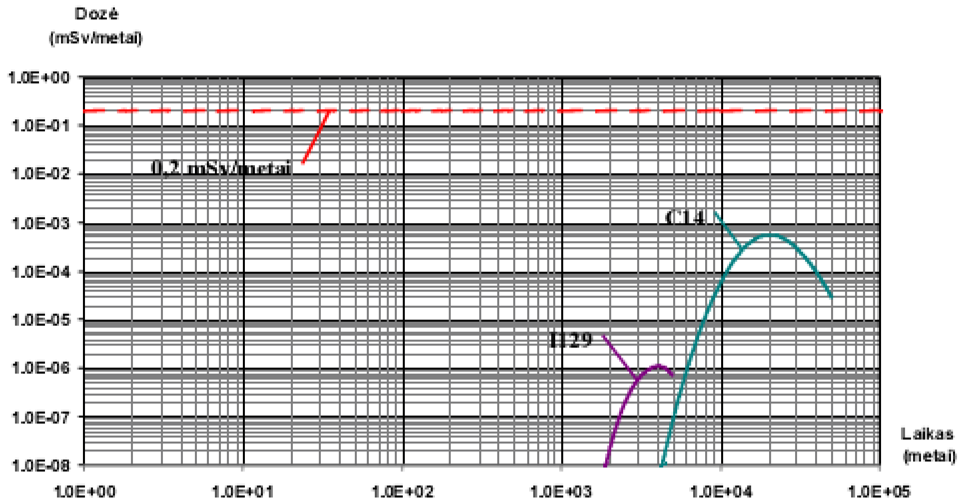
(
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.7. Effective doses (depending on time), caused by radionuclides migration for the site of Galilaukė according to natural development scenario when contaminated groundwater gets into the well drilled near the repository, and their comparison with the annual dose constraint of 0.2 mSv.

Results of calculations based on the scenario for the repository engineering barriers degradation

After the analysis of 18 radionuclides migration in the repository zone has been made, only 12 of them have been found to be reaching the biosphere zone by groundwater flows. The short-lived weakly sorbing ^{90}Sr radionuclide, the short-lived strongly sorbing ^{137}Cs and ^{241}Pu radionuclides, and long-lived ^{63}Ni, ^{241}Am and ^{238}Pu radionuclides would not reach the groundwater discharge points. The effective doses have been only assessed for those 12 radionuclides that have reached the biosphere: the short-lived radionuclide ^{3}H and the long-lived ones ^{14}C, ^{129}I, ^{59}Ni, ^{94}Nb, ^{99}Tc, ^{234}U, ^{235}U, ^{238}U, ^{237}Np, ^{239}Pu and ^{240}Pu. Time dependence of effective doses, caused by the assessed radionuclides, for the site of Galilaukė, where the supposed exposure pathway is the well drilled near the repository (150 m away from the vaults), is given in the Picture 4.3.2.9. As it can be seen from the results, the potential exposure would reach the maximum values – up to 0.036 mSv per annum – at the end of 3200-4000 years after the decommissioning (final closure) of the repository. By that time, a maximum influence would be that of ^{14}C radionuclide. The exposure caused by this radionuclide would be 5 times lower than an annual dose constraint equal to 0.2 mSv.

Time dependence of effective doses, caused by the assessed radionuclides, for the site of Apvardai, where one of the more important exposure pathway is the well drilled near the repository, is given in the Picture 4.3.2.10. It must be noted that when analyzing the latter exposure pathway, in calculations done for the migration of ^{14}C radionuclide, one of conservative suppositions listed in the Chapter Mathematical models has been disregarded. In calculations done for the migration of this radionuclide by groundwater flow, the two-dimensional radionuclide dispersion i.e. the influence not only in the longitudinal direction but also in the transversal direction of groundwater flow has been assessed. As it can be seen from the results, the potential exposure would reach the maximum values – up to 0.16 mSv per annum – at the end of 3200-4000 years after the decommissioning (final closure) of the repository. This exposure would be by 20% lower than an annual dose constraint – 0,2 mSv.

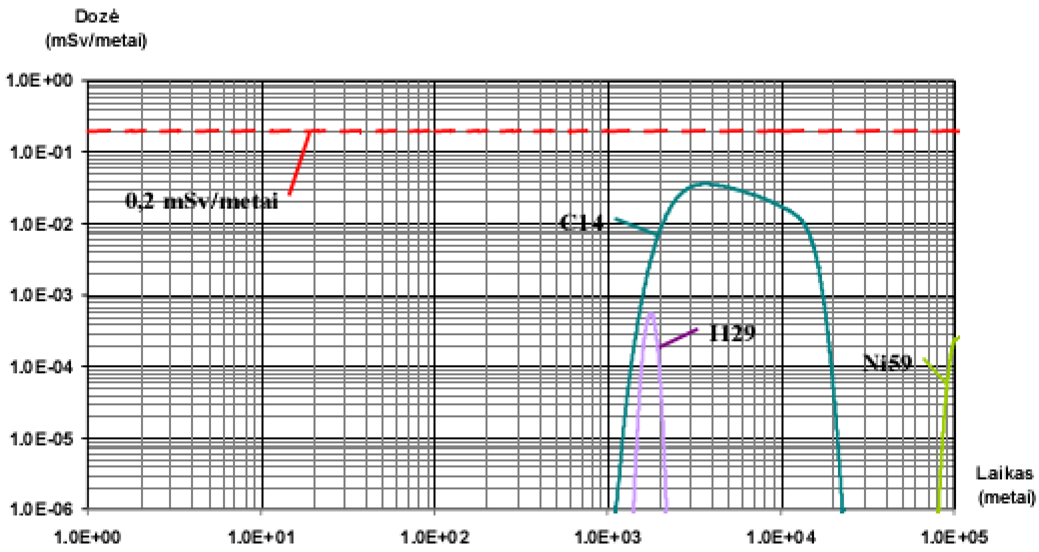


(
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.8. Effective doses (depending on time), caused by radionuclides migration for the site of Apvardai according to natural development scenario when contaminated groundwater gets into Apvardai lake, and their comparison with the annual dose constraint equal to 0.2 mSv.

Time dependence of effective doses, caused by the assessed radionuclides, for the site of Apvardai, where exposure pathway is the Apvardai lake situated at a distance of 1300 m from the repository, is given in the Picture 4.3.2.11. The potential expose in this case would be eight times less than dose limit. So, in the case of the site of Apvardai, dose limit would not be surpassed.

Having compared effective doses for the site of Apvardai and that of Galilaukė, it can be seen that, in case of Apvardai, where the layer of the zone of aeration and that of aquifer are much more thinner, and the migrating radionuclides would reach groundwater, as well as surface water, more quickly, the exposure would be by 20 % lower than an annual dose constraint of 0.2 mSv. In addition, when doing calculations of the exposure for the case of the well water, the dose limit has not been surpassed only when, in calculations for radionuclides migration in the groundwater, the less conservative two-dimensional case of dispersion, instead of the conservative one-dimensional case, has been analyzed.



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Dozė – dose (mSv/yr)
Laikas – time (years)
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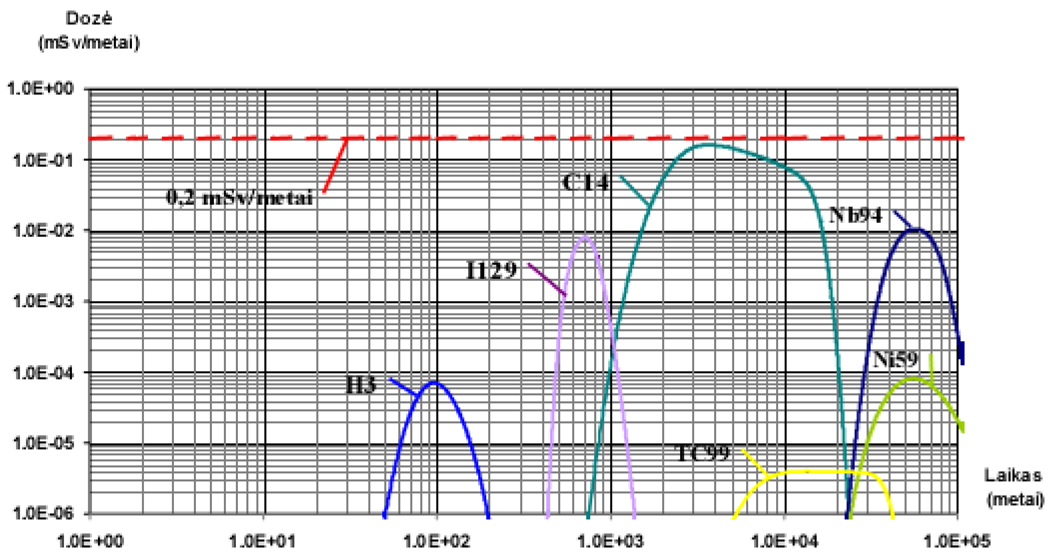
Picture 4.3.2.9. Effective doses (depending on time), caused by radionuclides migration for the site of Galilaukė according to engineering barriers degradation scenario when contaminated groundwater gets into the well drilled near the repository, and their comparison with the annual dose constraint equal to 0.2 mSv.



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Dozė – dose (mSv/yr)
Laikas – time (years)
)

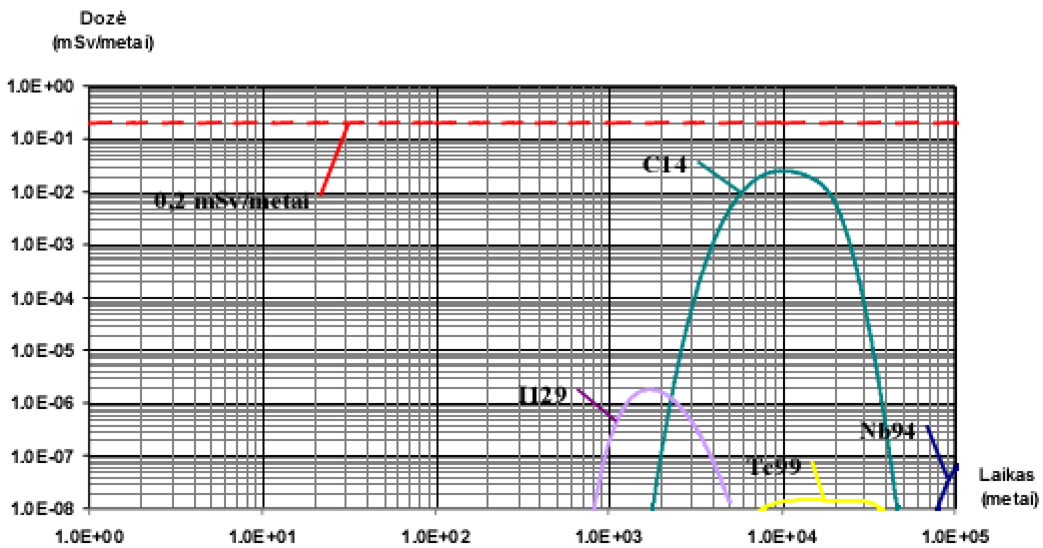
Picture 4.3.2.10. Effective doses (depending on time), caused by radionuclides migration for the site of Apvardai according to engineering barriers degradation scenario when contaminated groundwater gets into the well drilled near the repository, and their comparison with the annual dose constraint equal to 0.2 mSv.

Comparison of calculations results with safety criteria

The possible radionuclides migration from the near-surface repository due to engineering barriers degradation and population exposure caused by it have been assessed for the period of 100 thousand years after the final closure of the repository. An analysis has been made in view of geologic and hydrogeological conditions of the two sites provided for the construction of the repository.

The total annual effective dose caused by all radionuclides having reached biosphere has been calculated according to the *normal development* scenario:

- In the site of Galilaukė, it is less than $4.1 \cdot 10^{-4}$ mSv (according to biosphere well model);
- In the site of Apvardai, it is less than $9 \cdot 10^{-3}$ mSv (according to biosphere well model) and $6.2 \cdot 10^{-4}$ mSv (according to biosphere lake model).



(
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.11. Effective doses (depending on time), caused by radionuclides migration for the site of Apvardai according to engineering barriers degradation scenario when contaminated groundwater gets into the Apvardai lake, and their comparison with the annual dose constraint equal to 0.2 mSv.

The total annual effective dose caused by all radionuclides having reached biosphere has been calculated according to the *engineering barriers degradation* scenario:

- In the site of Galilaukė, it is less than 0.037 mSv (according to biosphere well model);
- In the site of Apvardai, it is less than 0.18 mSv (according to biosphere well model) and 0.025 mSv (according to biosphere lake model).

The calculated annual effective dose is lower than annual dose constraint of 0.2 mSv in both cases – the site of Galilaukė and that of Apvardai. The assessed potential exposure for the site of Galilaukė is lower than that of Apvardai.

The values $A_{i,max}$ of limiting activity of radioactive waste packages in the repository have been calculated based on the approved methods given in the regulatory document (*General ... of radioactive ..., 2003*), according to formula:

$$A_{i,\max} = (D_{\lim}/D_{i,\max}) \cdot A \;,$$

where i – the radionuclide assessed,

A_i – specific activity in a cask of the radionuclide i assessed,

$D_{\lim}$ – annual dose constraint (0.2 mSv),

$D_{i,max}$ – calculated maximum annual effective dose that could be received by any local person using the contaminated water for drinking from the well.

Values $A_{i,max}$ of limiting activity of radionuclides, which reached the biosphere zone, assessed for the scenarios in case of the site of Galilaukė and that of Apvardai, are given in Table 4.3.2.8.

The values of criterion $Y = \sum_i A_i / A_{i,\max}$ calculated in the case of both scenarios are given in Table 4.3.2.9. As one can see from the values given in the table, the criterion Y is fulfilled (all its values are less than 1) for both sites in all cases of the analysis. The values of criterion for the site of Apvardai are greater than those for the site of Galilaukė, and in the case of the barriers degradation scenario this value is nearly equal to 1.

Assessment of indeterminacies of calculation results

Indeterminacies that influence assessment of the impact may be grouped together (*IAEA. Safety Assessment..., 2004*) into the following main categories: 1) *Indeterminacies of scenario* – these are indeterminacies related to imprecisions of predictable evolution of the system; 2) *Indeterminacies of model* – these are related both to the simplifications of reality being applied in conceptual models and differences among mathematical models and simulation software; 3) *Indeterminacies of parameters* – these depend on the suitability of parameters to be used in a specific situation. If parameter values are determined by probabilistic distribution functions, the probabilistic analysis of uncertainties by using statistical modelling is possible. In this section, the radionuclides migration from near-surface repository by water flows and uncertainty of environmental impact assessment results, as well as possible errors in calculations, are discussed.

Two scenarios for possible evolution of the repository have been analyzed in this report – the more probable one of normal development of the repository and the less probable one of repository engineering barriers degradation. Both scenarios consider the natural concrete barriers degradation conservatively. It has been assumed that these barriers fully degrade and are no obstacle for the water flows through the repository after 300 years. In addition, the scenario for repository engineering barriers degradation takes into account that at the end of the institutional surveillance, due to unforeseen natural phenomena or human activities, the engineering barriers of the repository can be destroyed earlier than when being acted upon by only natural processes. The results of this scenario reflect the impact of the completely-destroyed repository on an environment 300 years after the final closure of the repository, without analyzing, what reasons caused such a degradation of the engineering barriers. By comparing pictures 4.3.2.6 and 4.3.2.9 (the site of Galilaukė) and 4.3.2.7 and 4.3.2.10 (the site of Apvardai), one can see the influence that the indeterminacies of the repository evolution exert upon the assessed doses. As it is seen, the maximum doses can differ in as much as 40 times or more but the dose limit is not surpassed.

Table 4.3.2.8. Calculated values of limiting activity of waste packages in cases of the analyzed scenarios for the site of Galilaukė and that of Apvardai.

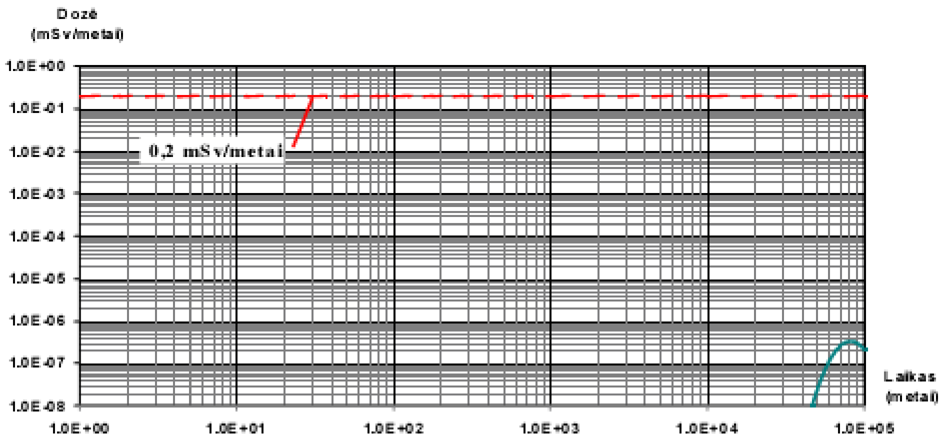
Radio-nuclide	**Values of Limiting Specific Activity $A_{i,\max}$, Bq/m³**			
	For the site of Galilaukė		**For the site of Apvardai**	
	Scenario for normal development	**Scenario for barriers degradation**	**Scenario for normal development**	**Scenario for barriers degradation**
H 3	$5{,}91 \times 10^{19}$	$1{,}32 \times 10^{16}$	$8{,}29 \times 10^{10}$	$8{,}29 \times 10^{10}$
C 14	$7{,}93 \times 10^{11}$	$7{,}74 \times 10^{9}$	$3{,}54 \times 10^{10}$	$1{,}71 \times 10^{9}$
I 129	$5{,}45 \times 10^{6}$	$5{,}41 \times 10^{5}$	$2{,}85 \times 10^{5}$	$3{,}81 \times 10^{4}$
Ni 59	$3{,}95 \times 10^{21}$	$7{,}6 \times 10^{9}$	$8{,}22 \times 10^{10}$	$2{,}4 \times 10^{10}$
Nb 94	8×10^{32}	$2{,}52 \times 10^{12}$	$2{,}93 \times 10^{13}$	$2{,}99 \times 10^{9}$
Tc 99	$1{,}52 \times 10^{11}$	$1{,}12 \times 10^{10}$	$1{,}16 \times 10^{10}$	$8{,}6 \times 10^{8}$
U 234	$7{,}94 \times 10^{10}$	$1{,}83 \times 10^{9}$	$5{,}68 \times 10^{9}$	$1{,}41 \times 10^{8}$
U 235	$1{,}37 \times 10^{10}$	$1{,}46 \times 10^{9}$	$1{,}05 \times 10^{9}$	$1{,}13 \times 10^{8}$
U 238	$2{,}57 \times 10^{9}$	$2{,}74 \times 10^{8}$	$1{,}98 \times 10^{8}$	$2{,}11 \times 10^{7}$
Np 237	$8{,}07 \times 10^{9}$	$6{,}47 \times 10^{8}$	$5{,}96 \times 10^{8}$	$4{,}95 \times 10^{7}$
Pu 239	-	$8{,}43 \times 10^{13}$	$5{,}26 \times 10^{16}$	$4{,}33 \times 10^{9}$
Pu 240	-	$6{,}48 \times 10^{25}$	$5{,}26 \times 10^{26}$	$9{,}16 \times 10^{11}$

Table 4.3.2.9. Criterion *Y* values for the proposed sites in the cases of analyzed scenarios.

Name of the site	**Scenario**	**Criterion *Y* value**
Galilaukė	Normal development	0.002
	Barriers degradation	0.18
Apvardai	Normal development	0.047
	Barriers degradation	0.90

When assessing radionuclides migration through the aeration zone, it has been assumed that radionuclides, after they have penetrated through the vault, are transported by water flow deep down to the nearest aquifer. This presumption is right for the site of Apvardai, the aeration zone of which is very narrow. In the site of Galilaukė, the aeration zone is larger, and, in reality, radionuclides migration can occur in different directions. Some part of radionuclides can be transported down to the nearest aquifer, while some other part of them can be taken away in the aeration zone by horizontal component of water flow, and then it can get either into the wells of the population who live near the repository or into adjacent surface water bodies, without having been transported down to the aquifer. In order to assess the influence of the possible horizontal component of water flow in the aeration zone of the site of Galilaukė on the radionuclides migration, an additional limit scenario has been analyzed. It has been conservatively assumed that all the radionuclides that have escaped the vaults of repository are transported in the zone of aeration, the thickness of which is 25 meters, density 1950 kg/m³, porosity 0.25, diffusion coefficient $1 \cdot 10^{-6}$ cm²/s, dispersion coefficient in the direction of the flow 15 m, hydraulic gradient

$8 \cdot 10^{-4}$, and the filtration coefficient $1 \cdot 10^{-7}$ m/s. It has been assumed that water contaminated by radionuclides gets into the habitant's well, which is situated next to the fence of the repository (150 m away from the vaults of it). Time dependence of the effective doses caused by the radionuclides migration for the site of Galilaukė, according to the scenario of normal development and that of engineering barriers degradation, is shown in pictures 4.3.2.12 and 4.3.2.13. During the period analyzed, only the radionuclide ^{14}C would get into the well. The possible maximum exposure would occur only 80 thousand years after the final closure of the repository and would reach approximately $3,3 \cdot 10^{-7}$ mSv per year. In case of engineering barriers degradation, the possible maximum exposure would occur only 70 thousand years after the final closure of the repository and would reach approximately $9,1 \cdot 10^{-6}$ mSv per year. As it can be seen, this radionuclides migration assessment scenario is less conservative than those ones assessed earlier, which consider only the vertical radionuclides migration in the aeration zone down to nearest aquifer, when the values of maximum doses would be by three-four orders greater.



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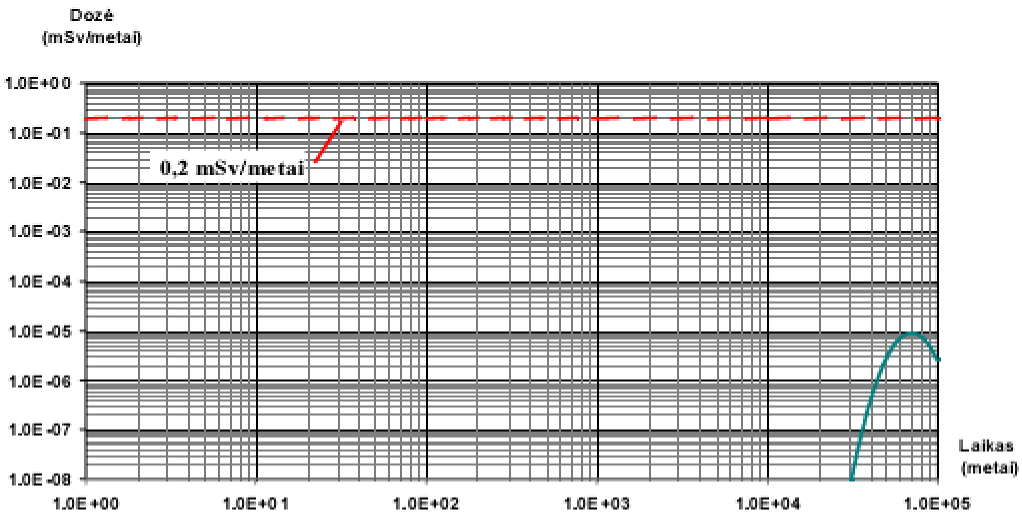
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.12. Effective doses (depending on time), caused by radionuclides migration for the site of Galilaukė, according to normal development scenario, when radionuclides are transported in the aeration zone by possible horizontal flow component and get into the well situated next to the repository.

When assessing other uncertainties both of mathematical modelling for radionuclide migration and parameters used in these models, it is necessary to underline the conservativeness of assumptions based on which these mathematical models have been created. The activity of disposed radioactive waste has been conservatively assessed, too. As it is noted in the Section "Mathematical models", the radioactive waste package, as an additional barrier for the migration of radionuclides, has not been assessed altogether. Dynamics both of infiltration of precipitation through the barriers of the repository and flooding (satiation) of it by water has not been assessed, as well, though the preliminary assessments (*Reference Design ..., 2002*) show that satiation of the repository by water can last for some hundred years. In the aeration zone and aquifer, in most of the cases, only one-dimensional (longitudinal) dispersion has been assessed, without taking into account the possible decrease of concentration due to transversal dispersion. Geosphere filtration coefficient values have been selected conservatively, though the laboratory tests show that the filtration coefficient values can be much lower (see Section 4.1). When choosing sorption coefficient values, the most probable ones, which in most cases are also conservative, have been taken. Because of the conservativeness of presumptions used in the calculations, the results of calculations for the radionuclides migration from the repository are to be considered as being conservative, too (the migration is overestimated). The overestimation of the radionuclides migration overestimates their possible impact on the environment (ionizing radiation exposure).



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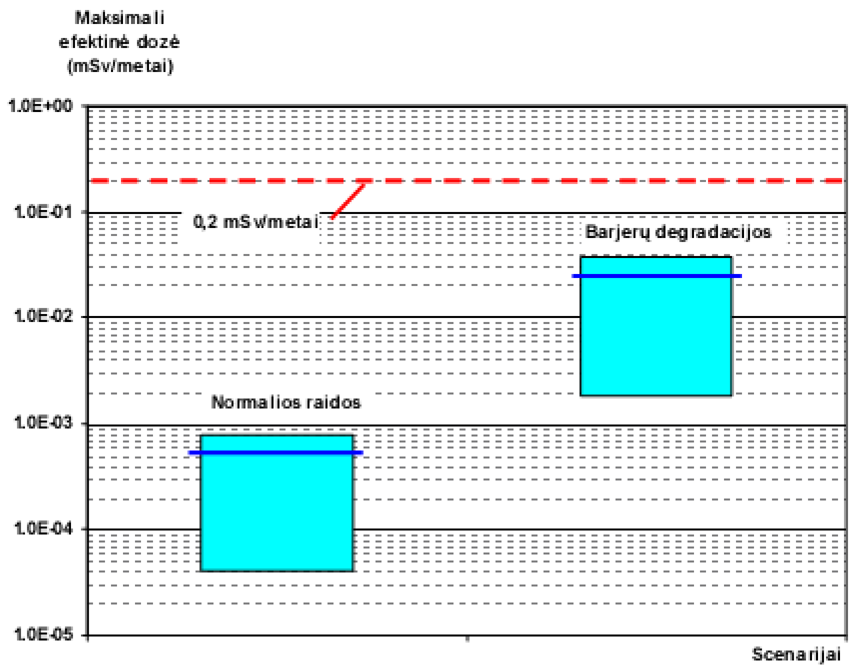
Dozė – dose (mSv/yr)
Laikas – time (years)
)

Picture 4.3.2.13. Effective doses (depending on time), caused by radionuclides migration for the site of Galilaukė, according to engineering barriers degradation scenario when radionuclides are transported in the aeration zone by possible horizontal flow component and get into the well situated next to the repository.

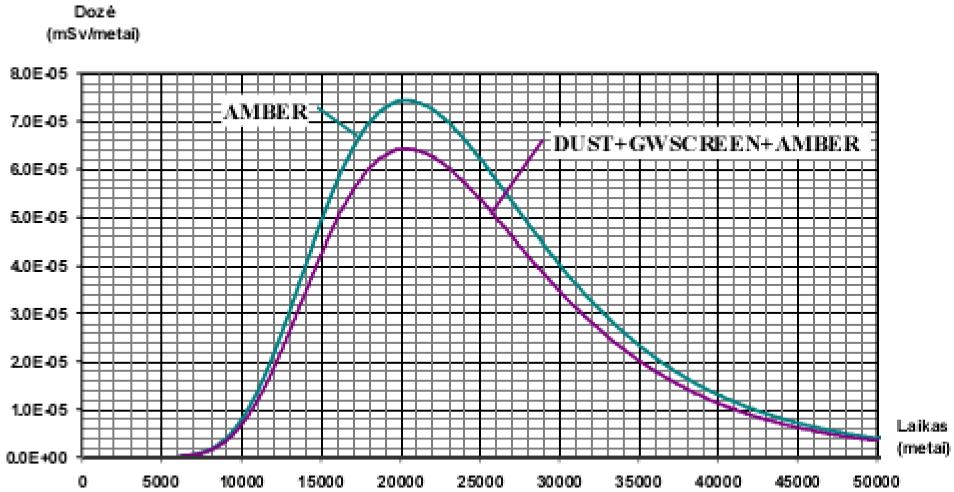
The influence of parameters uncertainty has been analyzed for the Apvardai lake biosphere model. As it can be seen from the above-given exposure calculations results, the radionuclides migration impact on the environment is greater. The exposure maximum doses are caused by ^{14}C radionuclide. The environmental impact of other radionuclides is considerably less. Therefore, when assessing the influence of lake biosphere model parameters uncertainty, the impact of these parameters on ^{14}C radionuclide maximum exposure dose value has been analyzed. Probabilistic distributions of model parameters, their limit, as well as most probable, values have been taken from the papers (*S. Karlsson ..., 2001, U. Bergström ..., 1999, U. Bergström ..., 2004*). Monte-Carlo statistical modelling software package AMBER has been used for the uncertainties analysis. Values of all the parameters used in the modelling were varied according to instructions given in the papers (*S. Karlsson ..., 2001, U. Bergström ..., 1999, U. Bergström ..., 2004*). Maximum exposure dose value dependence on the uncertainty of model parameters, caused by ^{14}C radionuclide migration, is given in Picture 4.3.2.14. In case of normal development scenario, the calculated value of maximum exposure dose caused by the ^{14}C radionuclide migration can vary in the range between $4.0 \cdot 10^{-5}$ and $7.3 \cdot 10^{-4}$ mSv per year (when using the most probable values of parameters, the value of dose is approximately equal to $5{,}5 \cdot 10^{-4}$ mSv per year). In case of engineering barriers degradation scenario, the calculated value of maximum exposure dose caused by the ^{14}C radionuclide migration can vary in the range between $1.8 \cdot 10^{-3}$ and $3.6 \cdot 10^{-2}$ mSv per year (when using the most probable values of parameters, the value of dose is approximately equal to $2.5 \cdot 10^{-2}$ mSv per year).

When assessing software-caused uncertainties, the influence of these have been assessed for the ^{14}C radionuclide migration in the site of Apvardai. The uncertainties in calculations done with the help of software have been assessed by calculating the radionuclide migration in different impact zones of the repository (near field, remote field and biosphere) by using different software packages. In first case, the environmental impact has been assessed with the help of software package DUST (to calculate the radionuclide migration in the repository and aeration zone), GWSCREEN (to calculate the radionuclide migration in aquifer), and AMBER (to simulate Apvardai lake biosphere). In second case, radionuclide migration in all the zones and the environmental impact have been assessed by using only the AMBER package. The results have been collated. Differences in calculated doses are: 10 % - for the normal development scenario (see Picture 4.3.2.15) and approximately 20 % - for the engineering barriers degradation scenario (see Picture 4.3.2.16). So, the uncertainties caused by the software used are not very significant.



(Picture 4.3.2.14:
Maksimali efektinė dozė – maximum effective dose (mSv/year)
0,2 mSv/metai – 0.2 mSv/year;
Barjerų degradacijos – barriers degradation;
Normalios raidos – normal development;
Scenarijai – scenarios.
)

Picture 4.3.2.14. Maximum exposure dose, caused by ^{14}C radionuclide migration, values dependence on the uncertainty of the parameters of Apvardai lake biosphere model for the scenario of repository normal development and that of engineering barriers degradation. Values of doses the calculations for which have been done by using the most probable values of parameters are marked with horizontal lines.



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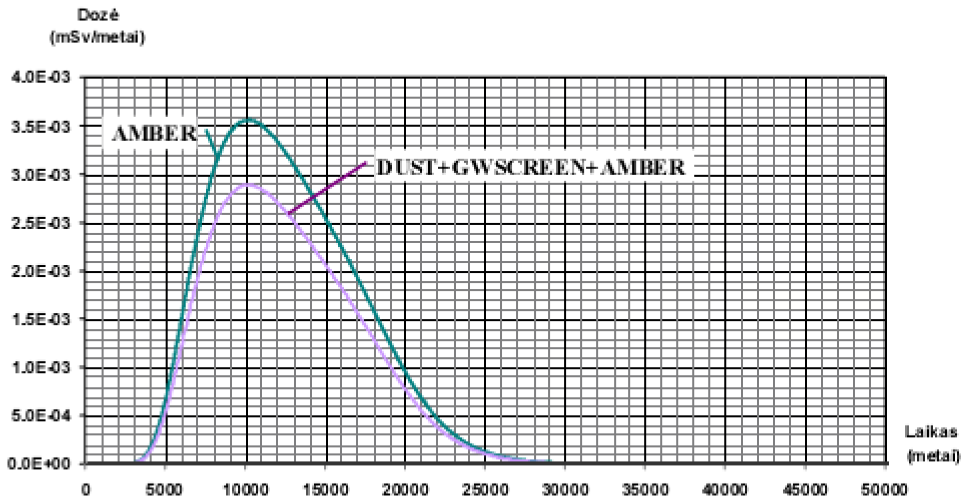
Dozė (mSv/metai) – dose (mSv/year);
Laikas (metai) – time (years).
)

Picture 4.3.2.15. Time-dependent effective doses caused by ^{14}C radionuclide migration for the site of Apvardai, according to *normal development* scenario, when contaminated groundwater gets into Apvardai lake, by calculating radionuclides migration with the help of only AMBER software, and when radionuclides migration in different zones has been calculated by using 3 different software packages – DUST+GWSCREEN+AMBER.



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Dozė (mSv/metai) – dose (mSv/year);
Laikas (metai) – time (years).
)

Picture 4.3.2.16. Time-dependent effective doses caused by ^{14}C radionuclide migration for the site of Apvardai, according to *engineering barriers degradation* scenario, when contaminated groundwater gets into Apvardai lake, by calculating radionuclide migration with the help of only AMBER software, and when radionuclide migration in different zones has been calculated by using 3 different software packages – DUST+GWSCREEN+AMBER.

Impact reducing measures

There are several possible ways of how to reduce the impact of ionizing radiation:

1. Right selection of criteria for acceptance of radioactive waste disposal;
2. Increasing the reliability of engineering barriers by choosing adequate structural materials and by ensuring good quality of work during construction;
3. Right selection of the surveillance period for the repository.

<u>THE SITE OF STABATIŠKĖ</u>

Exposure of population after the decommissioning of the repository

Due to either natural or premature degradation of the engineering barriers of the repository, the possible radionuclide migration by means of either groundwater or surface water flows can be the significant pathway of population exposure. In this section, the preliminary analysis of radionuclide migration by means of groundwater and surface water has been made, and an assessment of the possible ionizing radiation impact on the population, as well as the environment, has been given. The calculations *(Water flows ..., 2006)* have been done with the help of FEFLOW and AMBER software packages.

Concept of environmental impact assessment

The radionuclides migration through the pathways of groundwater and surface water and possible population exposure have been assessed in accordance with the ISAM (Improved Safety Assessment Methodology) methodology for the assessment of safety of a near-surface repository for radioactive waste prepared by IAEA (*IAEA. Safety Assessment…, 2004*, Picture 4.3.2.1).

Safety assessment task formulation

The scope of the analysis – to assess both the possible radionuclides migration by means of water flows and population exposure caused by it after the final closure of the waste repository.

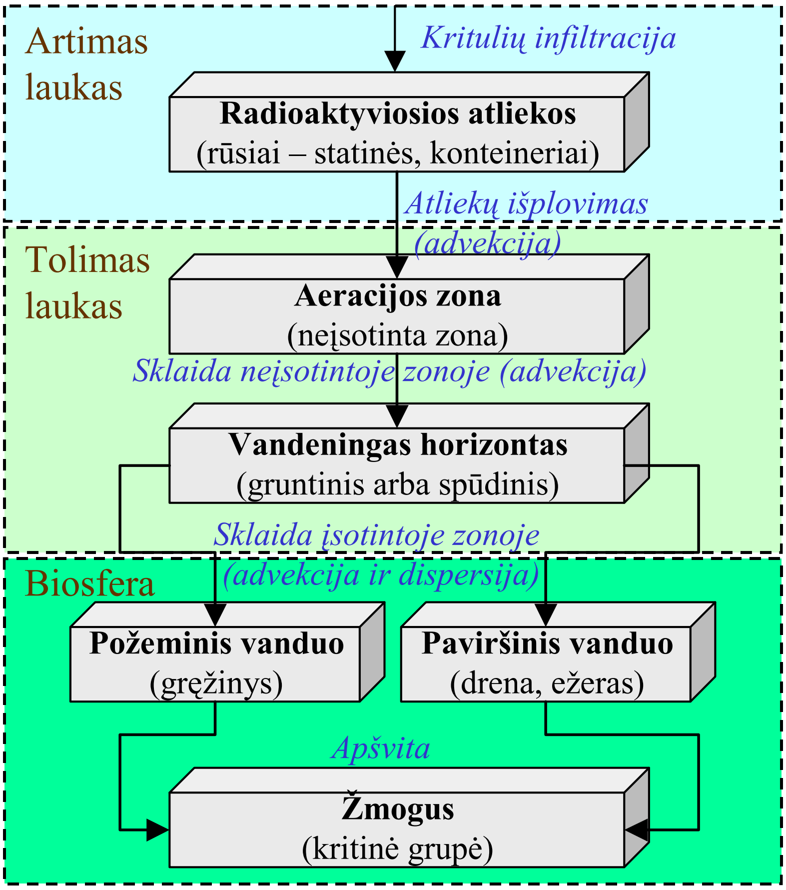
The analysis is made by considering the characteristics of the radioactive waste to be disposed of, the structural concept of a near-surface repository, and both the geological and hydrologic peculiarities of the site of Stabatiškė intended for the construction of repository.

The radiation safety criterion – annual effective exposure dose for the member of a critical population group. The annual effective exposure dose for the member of a critical population group, which is caused by the planned near-surface repository, must not exceed dose constraint applicable for the planned nuclear installations and which is equal to 0.2 mSv per annum (*LAND 42-2001*).

To assess both the radionuclides migration and its impact on the environment, the period of time of the repository development, including both its active and passive institutional surveillance, as well as a later period, during which the possibility of long-lived radionuclides getting into environment exists, has been analyzed. When doing calculations, it was supposed that active surveillance period is 100 years and that of passive surveillance – 200 years. During active surveillance period, a physical safety will be ensured, the monitoring of environment will be performed, the work of barriers maintenance will be done and, if needed, corrective measures will be taken. During the next, passive, surveillance period, after the end of that of active surveillance, the use of land in the territory of the repository will be limited, and restrictions on some type of activities will be applied (*Small and Medium ..., 2002*).

Radioactive waste disposal system description

Radionuclide migration from the near-surface waste repository by water flows can be initiated by precipitation (see Picture 4.3.2.17). Radionuclides that are washed off from the nuclear waste package by infiltrated water can leak through the bottom engineering barriers of the vault by way of advectional and diffusion transfer and get into aeration zone that is located beneath them. The water that fills the pores of aeration zone can transport radionuclides into the deeper-lying aquifer. Further, through aquifer, the radionuclides could reach, by way of water flows, the well of drinkable water, if the latter stood in the direction of the flow, discharge itself onto earth surface, spread into biosphere and result in both an external and internal exposure of population. In the assessment of radionuclide migration, three zones of radionuclide transportation are considered: the near field, which encompasses the repository, all the radioactive waste that is placed in it, and engineering barriers, which surround all the vaults of the repository; the remote field, which comprises aeration zone and aquifer; and biosphere with all surface waters, flora, fauna and humans.



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Artimas laukas – near field

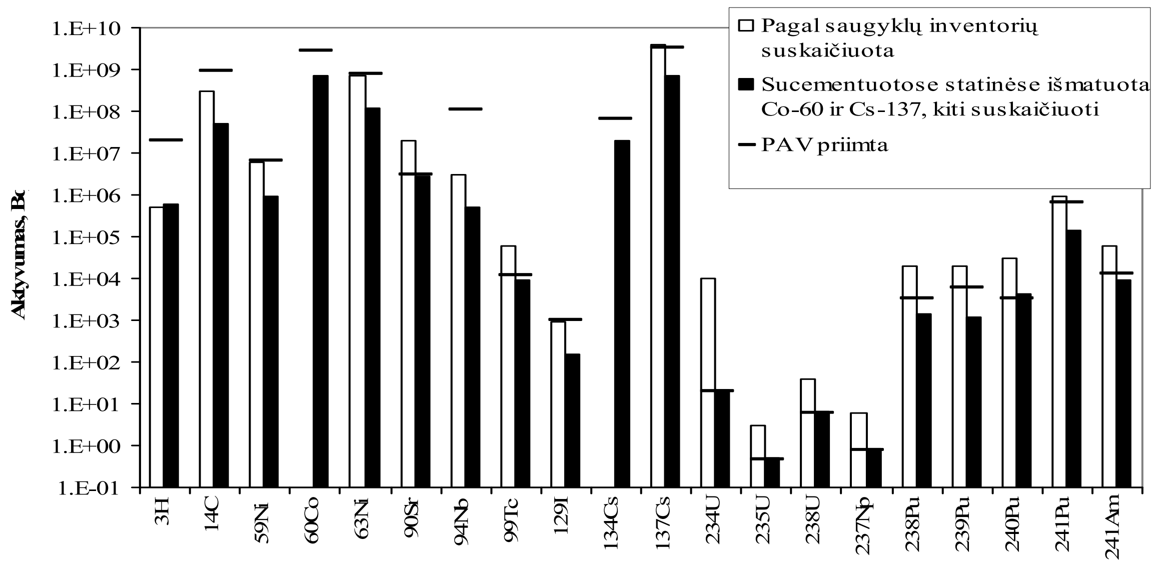
Kritulių infiltracija – precipitation infiltration

Radioaktyviosios atliekos (rūsiai – statinės, konteineriai) – radioactive waste (vaults with deposited drums, casks)

Atliekų išplovimas (advekcija) – washing away of waste (advection)

Tolimas laukas – remote field
Aeracijos zona (neįsotinta zona) – aeration zone (insatiated zone)
Sklaida neįsotintoje zonoje (advekcija) – migration in insatiated zone (advection)
Vandeningas horizontas (gruntinis arba spūdinis) – aquifer (groundwater)
Sklaida įsotintoje zonoje (advekcija ir dispersija) – migration in satiated zone (advection and dispersion)
Biosfera – biosphere;
Požeminis vanduo (gręžinys) – groundwater (borehole or well);
Paviršinis vanduo (drena, ežeras) – surface water (drain, lake);
Apšvita – exposure;
Žmogus (kritinė grupė) – a person (from critical group);
)
Picture 4.3.2.17. Common scheme for radionuclide migration components and processes.

The radioactive waste to be disposed of in the near-surface repository is characterized in the study (*Selection of a site ..., 2005*). The radionuclide composition of radioactive waste and concrete matrix (casks 0.2 m^3 capacity) activity values are given in Picture 4.3.2.18.



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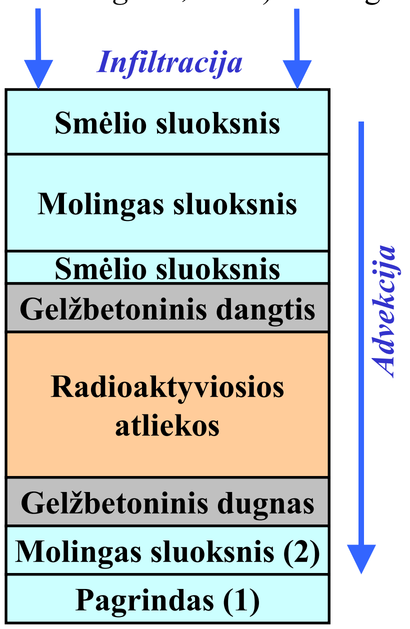
Aktyvumas, Bq – activity, Bq;
Pagal saugyklų inventorių suskaičiuota – counted according to the inventory of all the repository;
Sucementuotose statinėse išmatuota Co-60 ir Cs-137, kiti suskaičiuoti – in concrete matrix, Co-60 and Cs-137 have been measured, all other – calculated;
PAV priimta – accepted in PAV;
)
Picture 4.3.2.18. The radionuclide composition of radioactive waste and concrete matrix (casks 0.2 m^3 capacity) activity values.

In the assessment of the environmental impact, the activities of main mobile radionuclides have been conservatively assumed to be higher than those measured in the concrete casks. In the initial stage of radionuclides migration analysis, all of the radionuclides that are mentioned in the inventory have been analyzed. Data concerning physical (half-life) as well as chemical (sorption coefficients) properties of the assessed radionuclides are given in Table 4.3.2.10.

In initial stage of the assessment, after having simulated bulk activities of all the radionuclides in the water bodies nearest to the repository, it has been established that many short-lived and actively-sorbed radionuclides will in no way influence the environmental impact assessment results. The values of bulk activities in the nearest zones of groundwater situated at a distance of up to 80m from the module of the repository, which have the sense of being assessed, are inherent to only five radionuclides from all of those that are present in the waste: ^{14}C, ^{59}Ni, ^{94}Nb, ^{99}Tc and ^{129}I. The specifics of migration of these radionuclides from the repository depend on the properties of engineering barriers. Summary of characteristics of the repository module engineering barriers, which have been assessed in the analysis of radionuclide migration, has been made according to the data of the document (*Reference Design ..., 2002*) and is given in Picture 4.3.2.19 and Table 4.3.2.11.



(
Infiltracija – infiltration;
Smėlio sluoksnis – sand layer;
Molingas sluoksnis – clay based material layer;
Smėlio sluoksnis – sand layer;
Gelžbetoninis dangtis – reinforced concrete lid;
Radioaktyviosios atliekos – radioactive waste;
Gelžbetoninis dugnas – reinforced concrete bottom;
Molingas sluoksnis (2) – clay based material layer (2);
Pagrindas (1) – foundation (1);
Advekcija – advection.
)

Picture 4.3.2.19. Repository module engineering barriers concept and main parameters that cause radionuclides migration.

Table 4.3.2.10. Assessed radionuclides and their distribution coefficients for different environments.

Radio-nuclide	Half-life, years	Distribution (sorption) coefficient (K_4) in an environment, m^3/kg*							
		Cemen-ted radio-active waste	Con-crete	Clay foun-dation	sand-and-gravel mixture foundation	Aeration zone	Aquifer	Soil	Suspended matter in river or lake
^{3}H	12,4	0	0	0,0001	0	0	0	0,0001	0
^{14}C	5730	0,2	0,2	0,001	0,005	0,001	0,005	0,1	0,1
^{59}Ni	75400	0,04	0,04	0,67	0,01	0,3	0,4	0,67	10
^{60}Co	5,27	0,1	0,1	0,54	0,1	0,5	0,5	0,54	5
^{63}Ni	96	0,04	0,04	0,67	0,01	0,3	0,4	0,67	10
^{90}Sr	29,1	0,001	0,001	0,11	0,0001	0,02	0,013	0,11	1
^{94}Nb	20300	0,5	0,5	7,6	0,5	0,54	0,16	0,9	10
^{99}Tc	2,12e+5	0,5	0,5	0,0012	0,3	0,0001	0,00014	0,0012	0,005
^{129}I	1,57e+7	0,003	0,003	0,001	0	0,0045	0,001	0,18	0,01
^{134}Cs	2,06	0,001	0,001	2	0,01	2	0,4	1,8	1
^{137}Cs	30	0,001	0,001	2	0,01	2	0,4	1,8	0,05
^{234}U	2,45e+5	5	5	0,46	1	0,012	0,033	1,5	0,05
^{235}U	7,04e+8	5	5	0,46	1	0,012	0,033	1,5	0,05
^{238}U	4,47e+9	5	5	0,46	1	0,012	0,033	1,5	0,05
^{237}Np	2,14e+6	5	5	7,6	1	0,025	0,0041	0,055	0,01
^{238}Pu	87,7	5	5	7,6	1	1,2	0,54	4,9	100
^{239}Pu	24100	5	5	7,6	1	1,2	0,54	4,9	100
^{240}Pu	6540	5	5	7,6	1	1,2	0,54	4,9	100
^{241}Pu	14,4	5	5	7,6	1	1,2	0,54	4,9	100
^{241}Am	432	1	1	7,6	1	0,99	2	8,1	5

* Values taken from (*Project SAFE, ...2001; IAEA. Handbook ..., 1994*).

Table 4.3.2.11. Repository module engineering barrier parameters.

Barrier	**Material**	**Thickness, m**	**Dry material density, kg/m^3**	**Porosity**	**Filtration coefficient, m/s (when barrier is under operation)**
Sand layer	Sand	0,5	-	-	-
Clay material layer	Smectic clay	1,5	2000	0,25	1 10^{-10}
Sand layer	Sand	0,2	-	-	-

Reinforced concrete lid	Concrete	0,4	2300	0,15	$1\ 1^{-9}$
Radioactive waste	Concrete matrix	6,5	2000	0,25	$1\ 1^{-9}$
Reinforced concrete bottom	Concrete	0,6	2300	0,15	$1\ 1^{-9}$
Foundation	Sand-gravel mixture (1st alternative)	1	2000	0,40	$5\ 10^{-7}$
	Smectic clay (2nd alternative)	0,3	2000	0,25	$1\ 10^{-10}$

The summary of aeration zone characteristics (Table 4.3.2.12), assessed in the radionuclides migration analysis, has been made based on the summary of the results of geological and hydrogeological research for the Stabatiškė site (*Laikinųjų pjezometrų..., 2005*; *Račkauskas, Janulevičius, Abromavičiūtė, 2005; Račkauskas, Janulevičius, Abromavičiūtė, 2006*) done by the company UAB "GROTA", and the summary of aquifers characteristics (Table 4.3.2.13) – based on the summary of the research (*Račkauskas, Janulevičius, Abromavičiūtė, 2006*) done by the same company UAB "GROTA".

Table 4.3.2.12. Aeration zone parameters at the site of Stabatiškė.

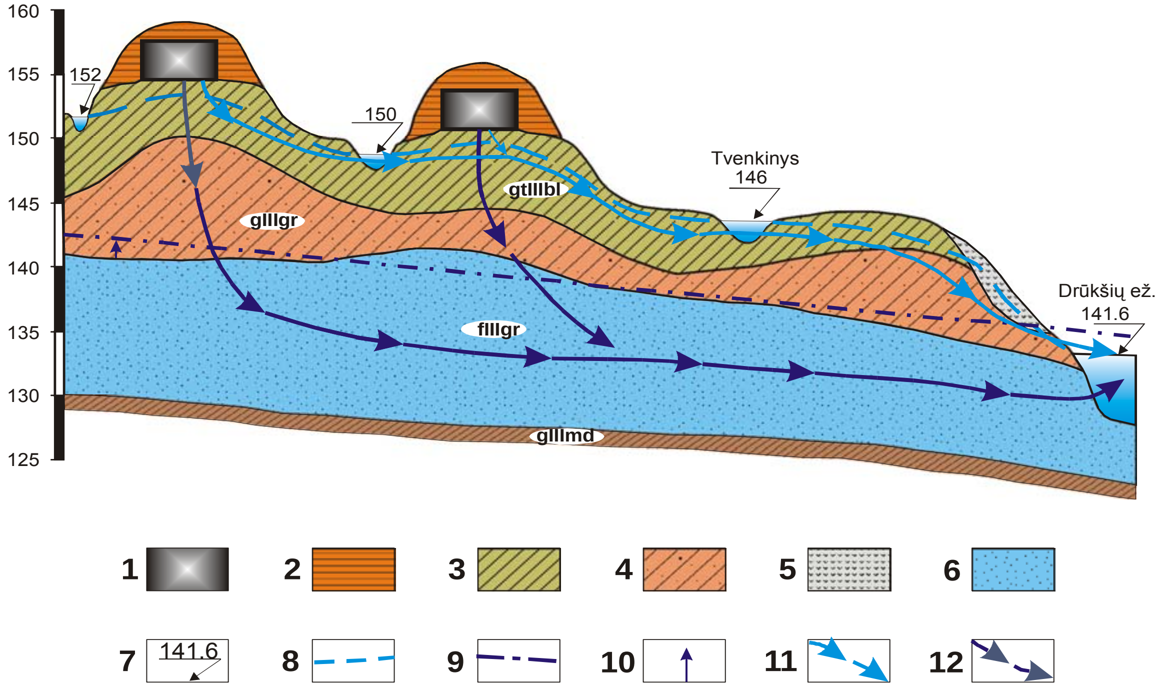
Watershed considered	**Material**	**Thickness, m**	**Dry material density, kg/m^3**	**Porosity**	**Filtration coefficient, m/s**
Near-surface aquifer – drainage – Drūkšiai lake	Glacial loam and moraine sandy clay with sandy insertions	1,5	1950	0,26	$3{,}8\ 10^{-08}$
Middle aquifer – Drūkšiai lake	Glacial loam and moraine sandy clay with sandy insertions	1,5	1950	0,26	$3{,}8\ 10^{-08}$

Table 4.3.2.13. Aquifers parameters at the site of Stabatiškė.

Watershed considered	**Material**	**Thickness, m**	**Dry material density, kg/m^3**	**Porosity**	**Filtration coefficient, m/s**	**Hydraulic gradient**	**Dispersion coefficient in the direction of flow, m**

Near-surface aquifer – drainage – Drūkšiai lake	Moraine sandy clay with sandy insertions	2,5-3,5	2100	0,30	1,0 10^{-06}	0,025	8 (80 m distance)
Middle aquifer – Drūkšiai lake	Varigrained dusty, gravel-like sand	19	2100	0,30	2,2 10^{-04}	0,001	177 (1770 m distance)

In the environment of the sites, the radionuclide-migration-in-biosphere pathways have been based on the conceptual hydrogeological model (see Picture 4.3.2.20), which has been created based on the analysis of hydrogeological conditions of the site.



(tvenkinys – pool;
Drūkšių ež. – Drūkšiai lake;
)

Picture 4.3.2.20. The conceptual hydrogeological model for Stabatiškė site (non-scale view): 1 – repository modules; 2 – engineering barriers; 3 – glacial loam, composing the upper sporadically-extended and season-dependent aquifer layer; 4 – moraine sandy clay; 5 – marsh sediments; 6 – sand-gravel sediments (middle aquifer); 7 – water level; 8 – upper aquifer layer; 9 – interlayer water piezometric level; 10 – head level above layer ridge; 11 – upper aquifer and drainage water flow direction (*first radionuclide transfer pathway*); 12 – middle aquifer flow direction (*second radionuclide transfer pathway*).

The two specific population exposure pathways, which cause maximum exposure doses, have been considered for the site: 1) at first, the water flow envelops the *upper sporadically-extended and season-dependent aquifer layer*, then it gets into the drainage system and quickly reaches *semi-confined middle aquifer*, discharges itself into southern bay of Drūkšiai lake; the operation borehole (well) is made 150 m away from the repository module. The first case reflects the situation with flooded site when surplus water is characteristic of surface zone. The second case reflects the situation with precipitation water infiltration deep down into the main aquifer. Radionuclides can reach people by two ways: first, through potable water well, and second, through Drūkšiai lake-related food chains. Main biosphere parameters are given in Table 4.3.2.14.

Table 4.3.2.14. Main biosphere parameters.

Parameter	**Value**
Average depth in southern bay of Drūkšiai lake ,m	3
Bay area, m^2	9,61e+6
Lake outflow capacity, $year^{-1}$	0,3
Root vegetables yield, kg/m^2	0,5
Leaf vegetables yield, kg/m^2	0,7
Crop yield, kg/m^2	0,4
Meat consumption per capita, kg/year	95
Dairy products consumption per capita, l/ year	287
Root vegetables consumption per capita, kg/ year	66
Green leafy vegetables consumption per capita, kg/ year	18
Crop products consumption per capita, kg/ year	124
Fish products consumption per capita, kg/ year	11
Water consumption per capita, l/ year	600
Time spent on contaminated soil, hours/ year	2922
Inhalation rate, m^3/val	1
Area of watered kitchen-garden, m^2	200
Depth of the upper layer of soil, m	0,25
Erosion, $year^{-1}$	0,0002
Water quantity swallowed by one livestock animal, l/day	60
Forage quantity consumed by one livestock animal, kg/day	55
Soil quantity swallowed by one livestock animal, kg/ day	0,6
Amount of suspended matter in water, kg/m^3	0,0008
Dust concentration in air, kg/m^3	5,33e-8

Creation and substantiation of scenarios for radionuclide migration in the environment

The scenarios can be created and picked out of those that are already available in several ways (*IAEA. Safety Assessment…, 2004*): *a)* by analyzing the list of important processes and events, which can influence a near-surface repository evolution, *b)* by using general scenarios created and analyzed for the likes of near-surface depositories or *c)* by applying a formalized procedure. In this report, the scenarios have been selected by applying a formalized procedure, which consists of four main steps:

1. The radioactive waste disposal system under consideration is divided into main components;
2. Characteristic states of the components are being defined;
3. The combinations of these states, together with scenarios based on them, are composed;
4. The scenarios are generalized and grouped together.

For the assessment of radionuclides migration impact, three radionuclides transfer geological environments (zones) have been singled out: near field, remote field (geosphere), and biosphere.

The near field, which encompasses radioactive waste and engineering barriers, can be in the following states:

- *stationary*: i.e. when engineering barriers retain their design properties. In this case, water will not penetrate into the repository or there will be only a minimum water flow depending both on the repository structure and engineering barriers properties;

- *naturally degraded*: the engineering barriers do not limit water flow into the repository; the influence of the flow depends on the natural conditions i.e. the amount of precipitation getting into the repository.

In this stage of analysis, it was supposed that the state of repository remains unchanged for the first 100 years after its decommissioning, during which the active institutional surveillance of the repository is provided and reparation work is done, if needed. Even for this period, it has been conservatively assumed that water flow through the repository is 5 times greater that it would in the case of unchanged-state engineering barriers. It has been also assumed that the repository enters the state of naturally degraded repository during its passive surveillance period (100 to 300 years after decommissioning of the repository). The concrete barriers underneath the repository heap begin to deteriorate and uniformly degrade. Nevertheless, the limitations that are put on all sorts of human activities in the territory of the repository for the passive surveillance period of the repository are enough to ensure that the repository is kept intact in all its entirety, with all the design properties being unchanged during this period. The significance of water flowing through the repository depends on the state of partly degraded concrete barriers as well as design hydraulic conductivity of clay barriers. At the end of institutional surveillance period (300 years after decommissioning of the repository) the engineering barriers of the repository can be in two states: either of natural degradation or total degradation. At the end of this period, totally degraded barriers of concrete, together with those of natural material (clay) that have retained their design properties, are inherent to the state of natural degradation.

Based on the defined states, in this stage of the analysis, one scenario for the evolution of engineering barriers of the repository has been created – the more probable one of *natural development* (see Table 4.3.2.15). The through-the-repository water flow values for all the states of engineering barriers have been assessed in accordance with the methods given in the report (*Reference Design ..., 2002*).

Table 4.3.2.15. Repository engineering barriers states and engineering barriers development scenarios.

Period of institutional surveillance	**Engineering barriers state**	**Water-through-repository flow, m per year**
Active (up to 100 years)	Unchanged	0.015
Passive (from 100 to 300 years)	In the course of natural degradation	0.015 – 0.021
No survaillance (over 300 years)	Naturally degraded	0.021

In this analysis, the near field (geosphere) and biosphere components are considered to be stable throughout the repository evolution. These components have no alternative states attached to them, except for two above-mentioned water pathways – through upper groundwater table and drainage system (the case of flooding), and also, through semi-confined middle aquifer (the case of infiltration deep down). In conservative assessment, the supposition is made that, in one case, all the radionuclides get into one water pathway, while in the other case – into another water pathway, i.e. the contaminated flow is not divided into two parts by any proportion deduced from 3D analysis.

Mathematical models

Radionuclides migration both in the repository and environment has been calculated by means of AMBER software package. When using this code, by solving linear differential equation systems that describe radionuclides mass exchange between compartments, it is possible to create the balance model for compartments. It is supposed that radionuclides are distributed uniformly in the volume of one compartment. By using the balance model, it is possible to solve one-dimensional problem – radionuclides transfer along the water flow lines, or, in some cases, – two-dimensional problem. Doses can be calculated, too (*Enviros QuantiSci ..., 2002*).

The way the activity of radionuclides varies in each compartment i is characterized by the differential equation:

$$\frac{dN_i}{dt} = \left(\sum_{j \neq i} \lambda_{ji} N_j + \lambda_M M_i + S_i(t)\right) - \left(\sum_{j \neq i} \lambda_{ij} N_i + \lambda_N N_i\right) \qquad (3),$$

where **i** and **j** – compartments the exchange of radionuclides between which is taking place, N and M – radionuclides activity (Bq) in compartment (M – parental radionuclide), S(t) – function of time for radionuclide N external source, Bq/year, λ - **i** and **j** part of the exchange between blocks (λ_{ji} and λ_{ij} - coefficients of radionuclide N transfer from compartment **i** into compartment **j,** and vice versa, in year^{-1}), λ_N - radionuclide N (year^{-1}) decay constant, λ_M - radionuclide M (year^{-1}) decay constant.

Radionuclide half-time, sorption properties and groundwater flows are causes that affect their migration in geosphere the most. With the help of AMBER software, based on known quantities (total activities) of the radionuclides present in the vaults of repository, it is possible to calculate either the radionuclide flows from the vaults into the environment, or initial bulk activities in the waste, cemented in the humidity of pores of waste.

When assessing radionuclide leaching from the repository, it is assumed that only vertical advection, according to Darcy's law, is acting. This assumption is quite conservative, because the radionuclide transfer rate, due to engineering barriers, as a matter of fact, is less. The expression of leaching constant λ_{leach} for any radionuclide is as follows:

$$\lambda_{leach} = \frac{q_{Adv}}{RD} = \frac{q_{in}}{\varepsilon DR} \qquad (4),$$

where q_{Adv} - water advection rate (**m/year**), q_{in} - water Darsy's velocity through porous media (equivalent to infiltration rate) (**m/ year**), ε - porosity of porous medium, filled by water, D – thickness of porous medium (repository or engineering barrier) (**m**), R – slowness factor, which is introduced from the coefficient of radionuclides distribution between liquid and solid state.

When radionuclides inventory in repository, leaching and decay constants are known, it is possible to determine a time-dependent radionuclides flow or initial bulk activities in the water flowing out of the repository or any other compartment:

$$C_c = \frac{Amount}{\varepsilon VR} \qquad (5),$$

where **Amount** – radionuclides inventory in a "compartment", V – "compartment" volume. These calculations are done with the help of AMBER software, by obtaining time-dependent bulk activities.

In spite of the fact that AMBER realizes only general model of the exchange between compartments, this package can be easily applied for the simulation of radionuclides transfer by groundwater flows in various complex hydrogeological conditions. In this work, a slightly modified, and tailored to local conditions, calculation system, which was presented in paper (*QuantiSci and Quintessa ..., 2000*), has been applied.

The following advection-dispersion equation describes the radionuclides transfer in one-dimensional groundwater flows:

$$R\ \frac{\partial C}{\partial t} = \frac{d_X}{\vartheta_w}\ \frac{\partial^2 C}{\partial x^2} - \frac{q}{\vartheta_w}\ \frac{\partial C}{\partial x} - R\ \ \lambda_T\ C\ + \sum_m R_m \lambda_m C_m \qquad (6),$$

where $\boldsymbol{x}$ – groundwater flow direction, $\boldsymbol{\vartheta_w}$ – effective porosity of the medium, $\boldsymbol{q}$ – groundwater Darsy's velocity **(m/year)**, $\boldsymbol{C}$ – radionuclide activity in groundwater **(Bq m^{-3})**, $\boldsymbol{d_X}$ – longitudinal dispersion coefficient (**m^2/ year**), approximately equal to $\boldsymbol{a_X q}$, where $\boldsymbol{a_X}$ **(m)** – longitudinal dispersionness, $\boldsymbol{\lambda_T}$ – radionuclide decay constant (**1/year**), $\boldsymbol{R}$ – slowness factor, which is introduced from the coefficient of radionuclides distribution between liquid and solid state, $\boldsymbol{C_p}$ – parental radionuclide activity (**Bq m^{-3}**), λ_p - parental radionuclide decay constant (**1/ year**). In the above-mentioned equation, the Darsy's velocity (***q*, m/year**) is calculated according to hydraulic conductivity and hydraulic gradient of the medium through which the water flows:

$$q\ = -K \frac{\partial H}{\partial x} \qquad (7).$$

When solving radionuclides dispersion equation, the area of groundwater flows is divided into compartments. The sufficient number of compartments depends on the ratio of advection and dispersion components of groundwater flow (*Scott, 1998*).

Dynamics both of infiltration through the repository barriers and repository filling by water (satiation), has not been assessed. It has been conservatively assumed that after the final closure of the repository the pores of radioactive waste packages, filler and casks are fully filled with water. In the near-surface repository, the immobilized (cemented) waste matrix is an important engineering barrier, the physical and chemical properties of which cause radionuclides migrate to the environment. The radionuclides separation from the waste matrix has not been analyzed. It has been supposed that radionuclides are solved in the water of medium pores and are uniformly distributed in the repository module after the equilibrium between liquid (water) and solid (absorbing matter) states has established.

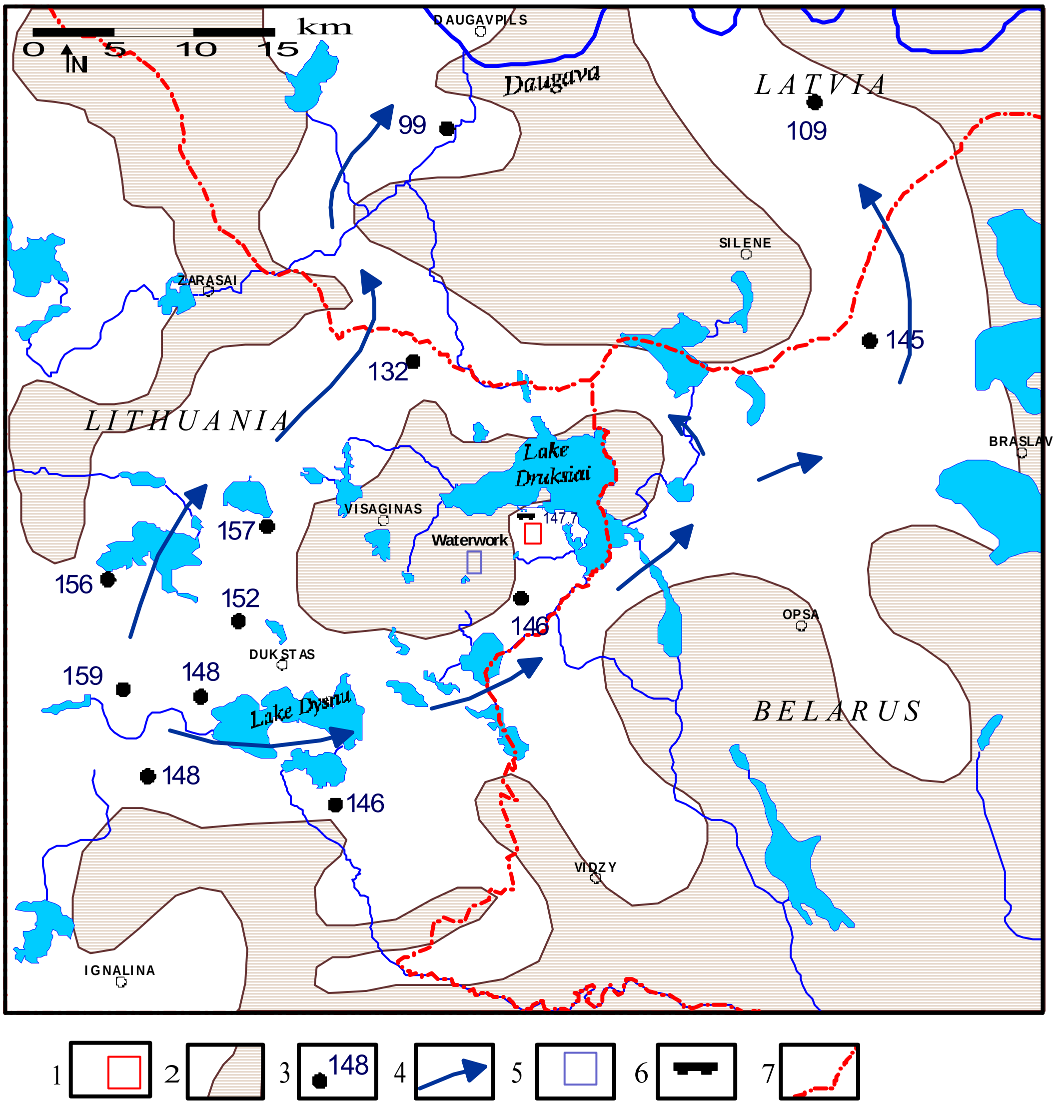
Physical and chemical processes that limit the radionuclides solvability has not been analyzed, too. The activity of radionuclides, which would be at the beginning of the operation of the repository, and not at that of an institutional surveillance, has been used, because it is not known yet what stages and quantities the waste is to be stored by in the repository after its construction. After the comparison of measurings of radionuclides activity in cemented casks with those used in calculations, it is obvious that the simulation analysis overestimates radionuclides activity in cemented casks (conservative supposition). The overestimation of radionuclides migration causes the overestimation of their environmental impact (ionizing radiation), too.

For the assessment of potential exposure of population, which people would experience by consuming water from the well (borehole drilled into the aquifer), the dose, which a person could get in the case the well is made by the near-surface repository, has been calculated. The size of the planned sanitary protection zone of the repository and limitations put on human activities in this zone have not been considered. It has been assumed that radionuclides after they have escaped a single vault get into the well, drilled at a distance of 80 m (the case of a surface groundwater – distance here is small because there's a marsh nearby) and 150 m (the case of middle aquifer – the well can be drilled at any distance because this aquifer is spread nearly all over the entire region of Ignalina NPP; see Picture 4.3.2.21) from the repository modules. The average consumption of water by local population per capita is 0.6 m^3 (600 litres) per year.

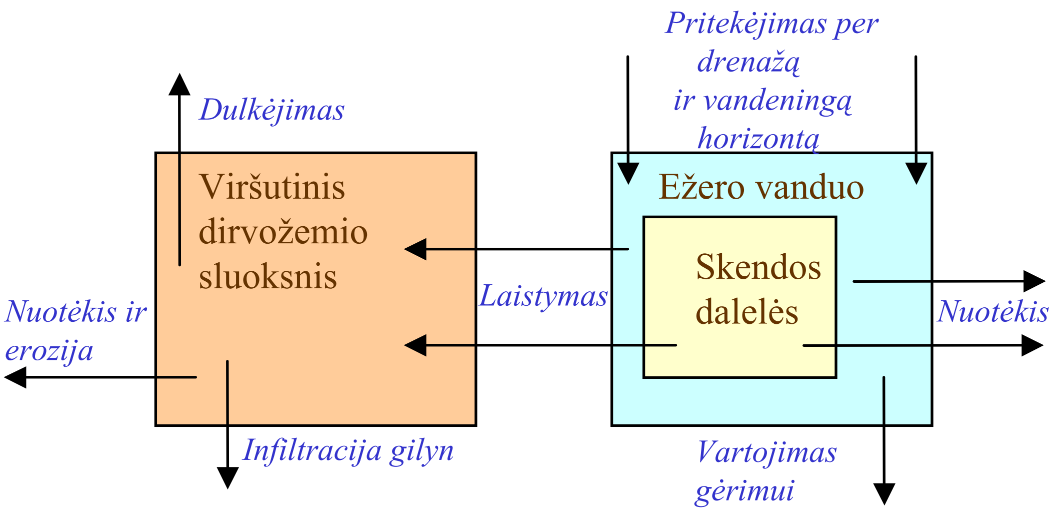
The potential population exposure, which they could get if radionuclides migrated into the southern bay of Drūkšiai lake by both water pathways. The linear differential equation, which simulates mass exchange of radionuclides between components of analyzed system (lake), has been solved by means of AMBER code. The conceptual model for radionuclides migration in lake (see Picture 4.3.2.22) has been created based on the works of (*Karlsson et al.…, 2001, Bergström et al.…, 1999, Bergström …, 2004*).

The parameters needed for the calculation, as well as their values, have been taken from papers (*Karlsson et al.…, 2001, Bergström et al.…, 1999, Bergström …, 2004, Filistovič et al.…, 1998, Nedveckaitė et al.…, 2000*). The most of parameters are the general ones, and some of them reflect local conditions. It has been assessed the total annual population exposure dose for a member of the population, which consists both of an external exposure, caused by a contaminated site, and internal exposure, caused by:

- Inhaled dust of the contaminated soil (when working outside);
- Potable water from the lake;
- Consumption of meat and milk obtained from the cattle that graze in the pasture watered by the lake water;
- Consumption both of root and green leafy vegetables, as well as corn products, watered by the lake water;
- Consumption of fish caught in the lake.



Picture 4.3.2.21. Scheme for the middle aquifer (agIII) prevalence in Ignalina NPP region: 1 – Location of Stabatiškė site in INPP region; 2 – aquifer boundary with aquitard; 3 – borehole location and groundwater level elevation; 4 – directions of water flows; 5 – area of Visaginas water intake; 6 – Ignalina NPP location in the region; 7 – the boundaries of states.



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Pritekėjimas per drenažą ir vandeningą horizontą – inflow through drainage and aquifer;

Ežero vanduo – lake water;

Skendos dalelės – suspended matter;

Nuotėkis – effluent;

Laistymas – watering;

Vartojimas gėrimui – usage for drinking;

Dulkėjmas – dusting;

Viršutinis dirvožemio sluoksnis – soil upper layer;

Nuotėkis ir erozija – effluent and erosion;

Infiltracija gilyn – infiltration into deep layers;

)

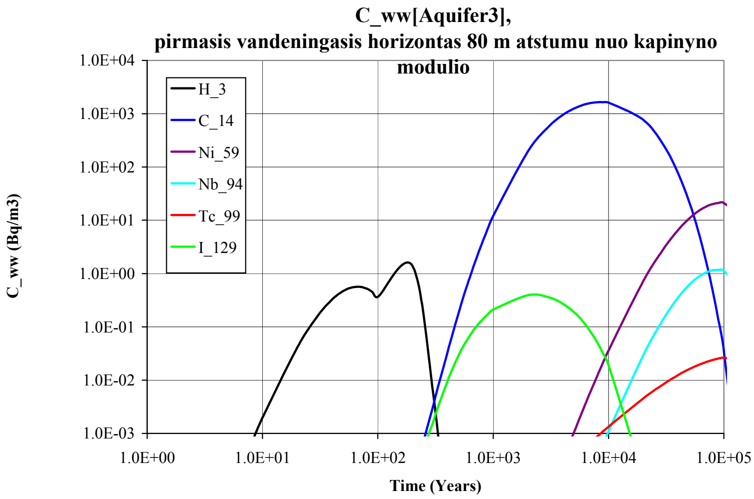
Picture 4.3.2.22. Conceptual model for the lake.

Results of calculations for the scenario of normal development of the repository

After the analysis of 19 radionuclides migration in the zone of the repository, as well as geosphere, had been made, it has been established that only 5 of them (^{14}C, ^{59}Ni, ^{94}Nb, ^{99}Tc, and ^{129}I) would reach the biosphere by the groundwater flow and form the discussed activities in the environment components (biota). The short-lived weakly sorbing ^{90}Sr radionuclide, the short-lived strongly sorbing ^{137}Cs and ^{241}Pu radionuclides, and long-lived ^{63}Ni, ^{241}Am, ^{238}Pu, and other radionuclides, would not reach the groundwater discharge points.

By using AMBER software, the effective doses for all the 19 radionuclides listed in the inventory of repository have been assessed, but in the analysis of calculations report, only the above-mentioned 5 radionuclides, together with ^{3}H, the activities of which though are low, their discharge-to-environment predictable time is short, are mentioned. In the upper aquifer at the distance of 80 m from the repository module, activities of these six radionuclides have been predicted in three cases (see Pictures 4.3.2.23-25): 1) cemented waste has been placed in casks, which have been placed in containers, with sand-gravel base underneath them; 2) cemented waste has been placed in casks without placing them in containers, with sand-gravel base beneath; 3) cemented waste has been placed in casks without placing them in containers, with clay base beneath.

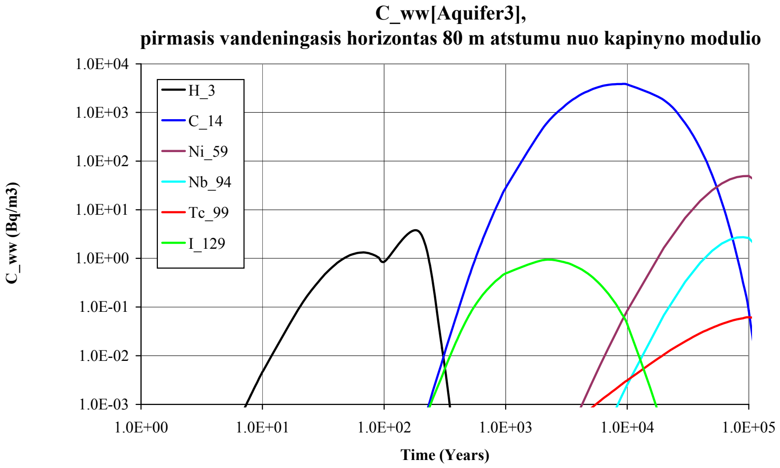
In all three cases, the maximum bulk activity in the groundwater is characteristic of ^{14}C. According to predictions, the peak activity will occur after 8000-9000 years. At that time, the activity of ^{14}C in groundwater would be: in first case – around 1800 Bq/m^3, in second case – around 4200 Bq/m^3, and in third case – around 4420 Bq/m^3. It is important to note that when there's a clay barrier, the bulk activity of ^{14}C in groundwater is a little bit higher compared with it in other cases, because the k_d values for this radionuclide in case of clay base are lower compared with them in the case of sand-gravel base (the thicknesses of these layers differ, too). For instance, at present, the bulk activity of ^{14}C in water of Drūkšiai lake is in the range of 10-20 Bq/m^3. The bulk activities of other radionuclides in groundwater will be significantly lower.



(pirmasis vandeningasis horizontas 80 m atstumu nuo kapinyno – the first aquifer at a distance of 80 m from the repository module)

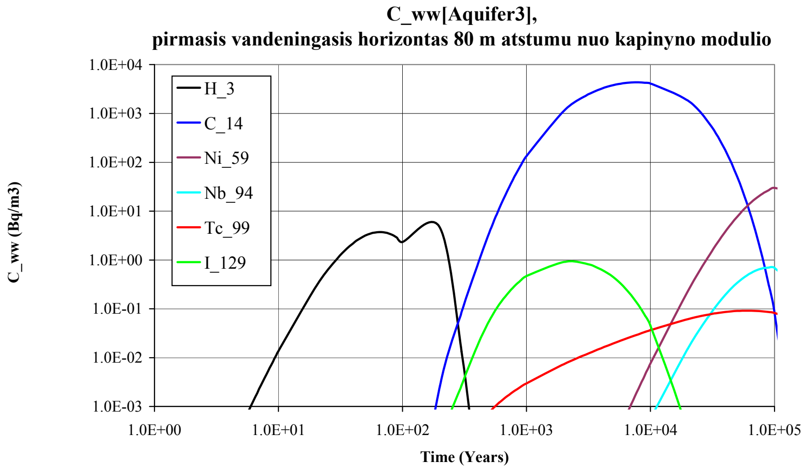
Picture 4.3.2.23. Time dependency of activities of main radionuclides in groundwater at a distance of 80 m from the repository when radioactive waste is put in casks, which are placed in containers, with sand-gravel base beneath.

The prediction of activity of six radionuclides in semi-contained aquifer 150 m away from the repository module has been made in two cases (see Pictures 4.3.2.26-4.3.2.27): 1) cemented waste is placed in casks, which are placed in containers, with sand-gravel base underneath them; 2) cemented waste is placed in casks without putting them in containers, with sand-gravel base beneath.



(pirmasis vandeningasis horizontas 80 m atstumu nuo kapinyno – the first aquifer at a distance of 80 m from the repository module)

Picture 4.3.2.24. Time dependency of activities of main radionuclides in groundwater at a distance of 80 m from the repository when radioactive waste is put in casks, without placing them in containers, with sand-gravel base beneath.

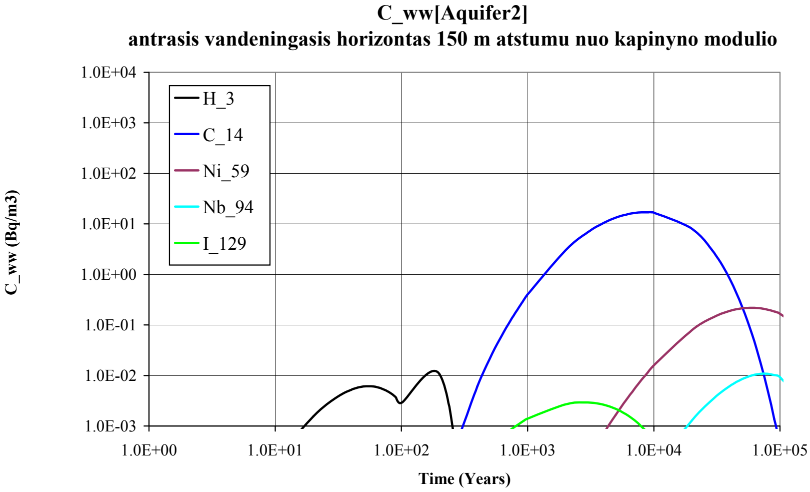


Picture 4.3.2.25. Time dependency of activities of main radionuclides in groundwater at a distance of 80 m from the repository when radioactive waste is put in casks, without placing them in containers, with clay base beneath.

In both cases, the highest bulk activity from that of all the radionuclides assessed in middle aquifer is characteristic of ^{14}C. The peak activity of this radionuclide is predicted to also occur after 8000-9000 years. At that time, the activity of ^{14}C in groundwater would be: in first case – around 19 Bq/m^3, in the second case – around 43 Bq/m^3.

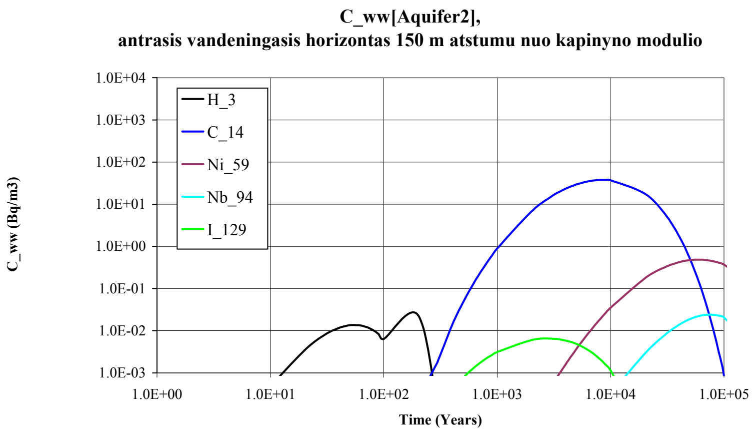
As it has already been mentioned, the effective doses have been assessed for all the radionuclides (see Table 4.3.2.16) but their values are illustrated here by the example of ^{14}C, because this radionuclide would cause the potentially highest exposure. In the model for the borehole (well), the maximum exposure caused by ^{14}C radionuclide is probable to occur in the course of 8-9 thousand years after the final closure of the repository and it would be of insignificant amount (lower by two orders) in comparison with the annual dose constraint, which is equal to 0.2 mSv. The exposure caused by some other radionuclides (e.g. ^{129}I) is even lower, and that of the most of them – infinitesimal.

Data on effective doses for two water pathways in the case of biosphere (southern bay of Drūkšiai lake) is given in graphs (see 4.3.2.28-4.3.2.29): the first water pathway is the upper aquifer and drainage system, the second water pathway – the middle semi-contained aquifer.



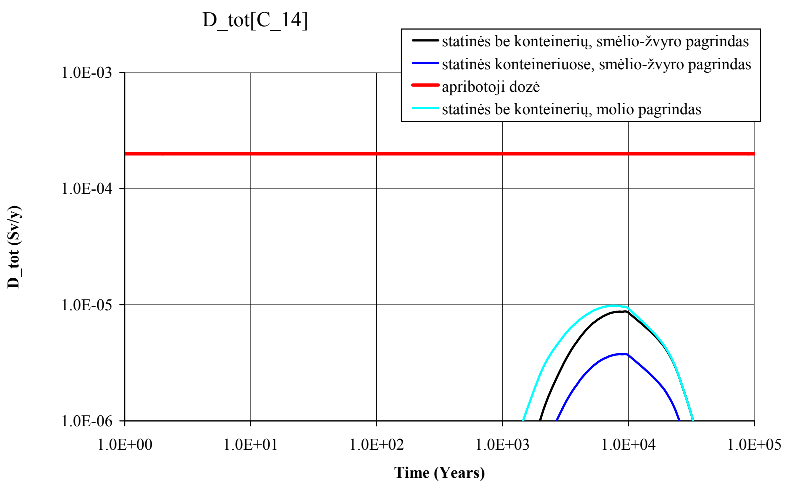
(antrasis vandeningasis horizontas 150 m atstumu nuo kapinyno – the second aquifer at a distance of 150 m from the repository module)

Picture 4.3.2.26. Time dependency of activities of main radionuclides in middle aquifer at a distance of 150 m from the repository when radioactive waste is put in casks, which are placed in containers, with sand-gravel base beneath.



(antrasis vandeningasis horizontas 150 m atstumu nuo kapinyno – the second aquifer at a distance of 150 m from the repository module)

Picture 4.3.2.27. Time dependency of activities of main radionuclides in middle aquifer at a distance of 150 m from the repository when radioactive waste is put in casks, without placing them in containers, with sand-gravel base beneath.



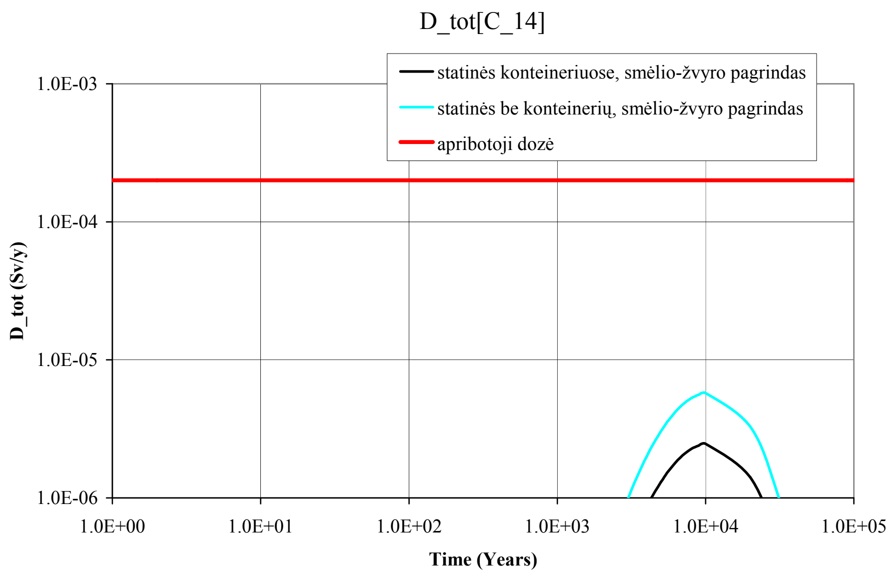
(statinės be konteinerių; smėlio-žvyro pagrindas – casks without containers, with sand-gravel base;

statinės konteineriuose; smėlio-žvyro pagrindas – casks in containers, with sand-gravel base;

apribotoji dozė – limit doze;

statinės be konteinerių; smėlio-žvyro pagrindas – drums without casks, with clay base.)

Picture 4.3.2.28. Effective doses for an adult, caused by ^{14}C radionuclide through all the exposure pathways that are related to the biosphere of Drūkšiai lake (the first water pathway is the upper aquifer and drainage system.)



(statinės konteineriuose; smėlio-žvyro pagrindas – drums in casks, with sand-gravel base;

statinės be konteinerių; smėlio-žvyro pagrindas – drums without casks, with sand-gravel base;

apribotoji dozė – dose constraint.

)

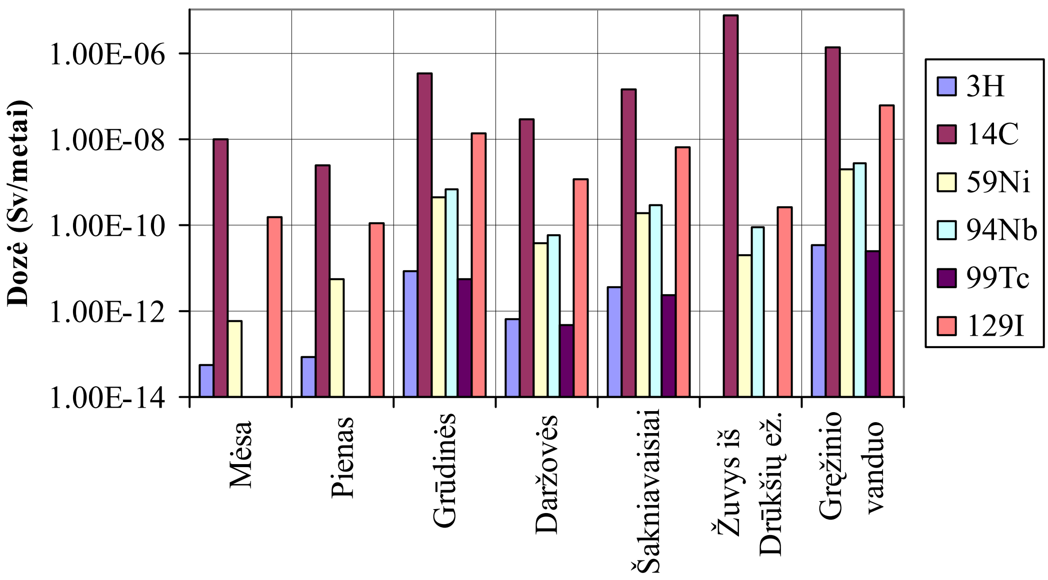
Picture 4.3.2.29. Effective doses for an adult, caused by ^{14}C radionuclide through all the exposure pathways that are related to the biosphere of Drūkšiai lake (the second water pathway – the middle semi-contained aquifer.)

In all the internal exposure pathways, though not high but relatively highest effective dose is caused by ^{14}C, in second place is ^{129}I, in third – ^{94}Nb, and in fourth – ^{59}Ni. A person can get the maximum exposure through the consumption of fish caught in Drūkšiai lake, in the second place it would be the water taken from well, and in third – the consumption of vegetables (see Picture 4.3.2.30).

Table 4.3.2.16. Main results of radionuclide migration and effective dose assessment (drain to Drūkšiai lake, casks without containers, the most conservative case).

Radionuclide	Peak activity in aquifer at a distance of 80 m, Bq/m^3	Time until peak moment, years	Predicted effective dose of exposure, caused to members of a critical group of population by different exposure pathways, Sv/year										
			Cattle meat	Milk	Crop products	Vegetables	Root vegetables	Fish	Water from well	Internal through food	Internal through inhalation	External	Drūkšiai lake water
^{3}H	1,3 3,3	70 200	5.3e-14	8.3e-14	8.1e-12	6.7e-13	3.5e-12	<<	3.5e-11	**4.8e-11**	<<	<<	1.9e-13
^{14}C	3845	9000	9.2e-9	2.3e-9	3.2e-7	2.7e-8	1.4e-7	6.9e-6	1.3e-6	**8.7e-6**	<<	<<	7.5e-9
^{59}Ni	49	100000	5.6e-13	5.4e-12	4.5e-10	3.7e-11	1.9e-10	1.9e-11	1.9e-9	**2.6e-9**	<<	<<	1.0e-11
^{60}Co	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{63}Ni	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{90}Sr	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{94}Nb	2,7	90000	<<	<<	6.7e-10	5.6e-11	2.9e-10	8.6e-11	2.8e-9	**3.9e-9**	**7.3e-16**	**9.5e-11**	1.6e-11
^{99}Tc	0,06	100000	<<	<<	5.6e-12	4.7e-13	2.4e-12	<<	2.4e-11	**3.2e-11**	<<	<<	1.3e-13
^{129}I	0,9	2000	1.5e-10	1.1e-10	1.4e-8	1.2e-9	6.2e-9	2.5e-10	6.0e-8	**8.3e-8**	**3.8e-17**	**3.3e-15**	3.4e-10
^{134}Cs	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{137}Cs	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{234}U	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{235}U	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{238}U	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{237}Np	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{238}Pu	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{239}Pu	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{240}Pu	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{241}Pu	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<
^{241}Am	<<		<<	<<	<<	<<	<<	<<	<<	<<	<<	<<	<<

<< too small values, not worth of assessment.



(Dozė (Sv/metai) – dose (Sv/year);
Mėsa – meat;
Pienas – milk;
Grūdinės – corn products;
Daržovės – vegetables;
Šakniavaisiai – root vegetables;
Žuvys iš Drūkšių ež. – fish from Drūkšiai lake;
Gręžinio vanduo – water from borehole (well).
)
Picture 4.3.2.30.

Comparison of calculation results with safety criteria

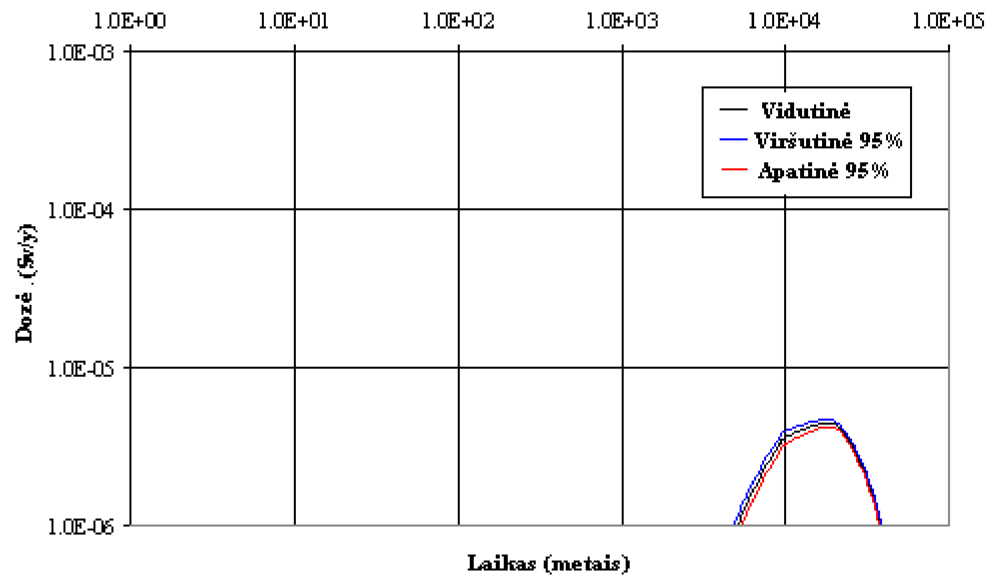
The possible radionuclides migration from near-surface repository due to engineering barriers degradation and population exposure caused by it has been assessed for 100 thousand years after the final closure of the repository. The analysis has been made by considering geological and hydrogeological conditions for the site of Sabatiškės intended for the construction of the repository.

All the annual effective dose caused by radionuclides that have reached the biosphere, which has been calculated according to the scenario for the normal development of the repository in the most conservative case, doesn't exceed 1.5×10^{-3} mSv, according to groundwater well model, and 9×10^{-3} mSv, according to bioshere (lake) model.

Assessment of indeterminacy of calculation results

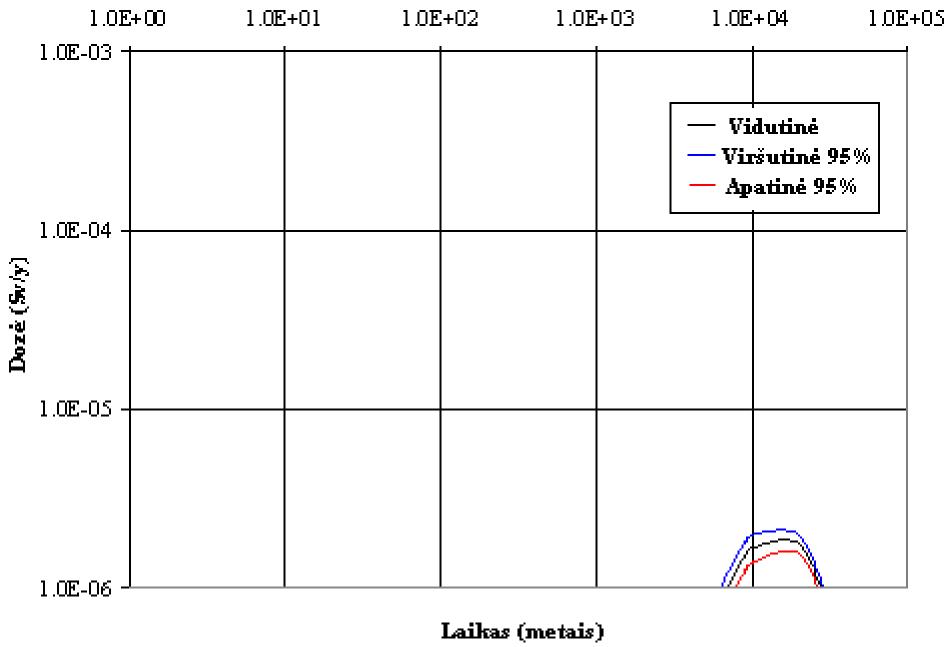
Indeterminacies that influence assessment of the impact may be grouped together (*IAEA. Safety Assessment…, 2004*) into the following main categories: 1) *Indeterminacies of scenario* – these are indeterminacies/uncertainties related to imprecisions of predictable evolution of the system; 2) *Indeterminacies of model* – these are related both to the simplifications introduced in conceptual models for the engineering reality and nature and differences among mathematical models and simulation software; 3) *Indeterminacies of parameters* – these depend on the suitability of parameters to be used in a specific situation of the medium. If parameter values are determined by probabilistic distribution functions, the probabilistic analysis of uncertainties by using statistical modelling is possible.

In this stage of work, the uncertainties both of scenario (cemented waste placed in casks, which placed in containers, with sand-gravel base; cemented waste placed in casks, without placing them in containers, with sand-gravel base; cemented waste placed in casks, without placing them in containers, with clay base) and model (the first water pathway – through upper aquifer and drainage system, the second pathway – through middle semi-contained aquifer). Having analyzed extreme cases, one can see that values of maximum doses may differ among each other by up to one order but the dose constraint is not exceeded.

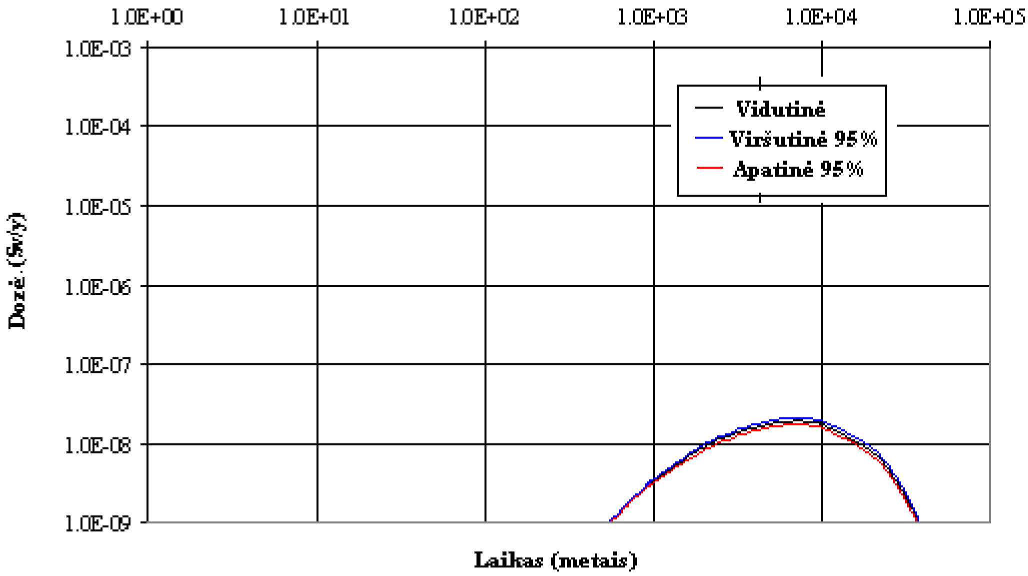


(Dozė – dose;
Vidutinė – average;
Viršutinė – upper;
Apatinė – lower;
Laikas (metais) – time (years).
)

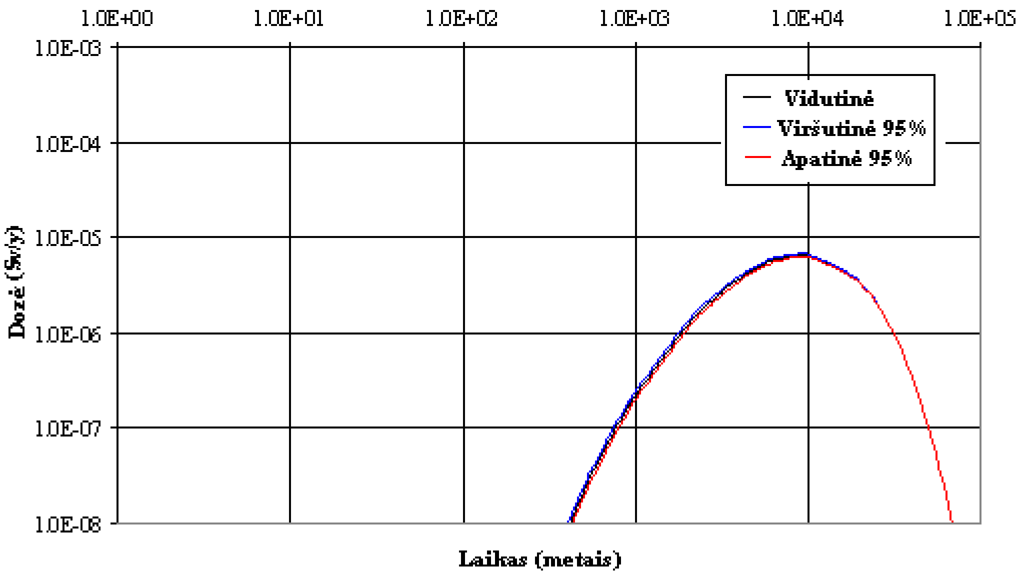
Picture 4.3.2.31. Effective doses for an adult, caused by ^{14}C radionuclide, if the water from well is being consumed (the first water pathway – through upper aquifer and drainage system; the barriers are degraded, uncertainties caused by filtration coefficient).



Picture 4.3.2.32. Effective doses for an adult, caused by ^{14}C radionuclide through all possible exposure pathways connected to Drūkšiai lake biosphere (the first water pathway – upper aquifer and drainage system; the barriers are degraded, uncertainties caused by filtration coefficient).



Picture 4.3.2.33. Effective doses for an adult, caused by ^{14}C radionuclide, if the water from well is being consumed (the second water pathway – through the middle semi-contained aquifer; the barriers are degraded, uncertainties caused by filtration coefficient).



Picture 4.3.2.34. Effective doses for an adult, caused by ^{14}C radionuclide through all possible exposure pathways connected to Drūkšiai lake biosphere (the second water pathway – through the middle semi-contained aquifer; the barriers are degraded, uncertainties caused by filtration coefficient).

***Preliminary conclusions**:*

According to preliminary results of calculations for the scenario of normal development, based on conservative presumptions, the population exposure maximum dose is approximately equal to $1.5 \cdot 10^{-6}$ Sv/year for the model for the well drilled into the upper aquifer (the case of flooding) and $1.5 \cdot 10^{-8}$ Sv/year for the model for the well drilled into the middle aquifer. The maximum effective dose in case of lake model (exposure pathways: consumption of crop products, root vegetables, green leafy vegetables, beef, milk, fish; external exposure; inhalation; consumption of lake water for drinking), when pathways of upper aquifer and wastewater from drainage system connecting the repository and lake exist, would not exceed $9.0 \cdot 10^{-6}$ Sv/year, and when the repository and lake is connected through the middle semi-contained aquifer – $6.5 \cdot 10^{-6}$ Sv/year.

Maximum annual exposure doses for the critical group of population will not exceed the established unregulated level ($1.0 \cdot 10^{-6}$ Sv/year). The repository, in view of radiation protection, can be constructed at Stabatiškė site. By preliminary assessment, special measures for the impact reduction are not necessary.

The abbreviations used in pictures 4.3.2.23-29 and 4.3.2.31-34 are as follows:

Adv_cap	water through-the-repository (also, through the aeration zone) advection capacity, m/year;
DF_ext	dose coefficient from the external radiation of a soil, (Sv/h)/(Bq/kg) (for the external exposure dose power);
DF_ing	effective dose factor for a person when a single radionuclide activity gets into the body by way of ingestion, Sv/Bq;
DF_inh	effective dose factor for a person when a single radionuclide activity gets into the body by way of inhalation, Sv/Bq;
Drain_flow	drainage system yield, m^3/year;
Depth	depth (height) of “compartment”, m;
Drum_Number	the number of structures in a module;
Drum_act	activity of radionuclides in a cask, Bq/m^3;
Int	average irrigation water intake by crop;
Irrig	irrigation water infiltration (into soil) rate, m/year;
K	filtration coefficient, m/year;

Length	length of "compartment", m;
Num_Dunits	the number of modules in repository;
Occup	the overall number of hours spent by a person near lake per year, hours/year;
Q_Cow	animal products consumption, kg/ year (meat), l/ year (milk);
Q_crop	vegetable products consumption, kg/ year;
Q_fish	fish consumption, kg/year;
Q_wat	potable water consumption, m^3/ year;
Riv_flow	river flow debit, m^3/year;
TF_Crop	concentration coefficient for crop, (Bq/kg humid weight)/(Bq/kg dry weight);
TF_Fish	concentration coefficient for fish, (Bq/kg)/(Bq/m^3);
TF_animal	transport coefficient for animal products, 24-hours/kg;
WasteRatio	the part of repository that is filled by radioactive waste;
Yield	consumed crop yield, kg/m^2;
dH_dx	hydraulic gradient;
dist_down	distance from the source (of each "compartment"), m;
dist_out	length of flow path, m;
eros	soil erosion rate, 1/year;
k_s	coefficient of distribution between surface water and suspended matter, m^3/kg;
kd	coefficient of distribution between filtering water and porous medium, m^3/kg;
part	suspended matter in river and lake, kg/m^3;
q_pasture	forage consumption (by animals), kg/24-hours;
q_soil	soil consumption (by animals), kg/24-hours;
q_water	water consumption (by animals), m^3/d.;
rho_bd	bulk density of solids, kg/m^3;
rho_wat	water density, kg/m^3;
theta_w	porosity of matter filled by water.

4.3.3. Ambient air

Exposure of population

As only solidified radioactive waste the packages of which meet the established regulations for the safe transportation of radioactive waste *(Regulations for the Safe ..., 2004)* and the eligibility criteria for the disposal of radioactive waste in the near-surface repository *(Bendrieji radioaktyviųjų ..., 2003)* will be accepted for disposal at the repository, radionuclides shall not be released into the atmosphere as aerosol or gas, if the repository is normally operated; therefore, their impact shall not be analysed.

Another situation will arise during the stage following the closure of the repository; therefore, the potential formation of flammable and explosive gas and possible results of such formation must be assessed. Gas may be formed in a closed repository as a result of the corrosion of metals, microbiological decay of organic substances and the radiolysis of water. As stated in TECDOC-1397 of the IAEA *(Long Term Behaviour ..., 2004)*, Swedish SKB studies *(Gas Generation ..., 1999; Gas Related ..., 2001)* and other papers, even in low and intermediate level radioactive waste repositories fully flooded by water the amounts of gas released as a result of the radiolysis of water amount to only a hundredth of the amount of gas resulting from the corrosion of metals; therefore, in our case the radiolysis of water is insignificant and will not be analysed any further. Further analysis shall cover two principal sources for the release of gas, viz. the corrosion of metals (iron, aluminium, zinc) contained in waste as well as waste packages (drums, cask body) and the microbial decay of organic substances, such as paper, rags, cotton, timber, plastic and rubber.

Principal chemical reactions for the corrosion of iron and steel are as follows:

$$4Fe + 3O_2 \text{ ---------------------> } 2Fe_2O_3 \quad (1)$$

$$3Fe + 4H_2O \text{ --------------------> } Fe_3O_4 + 4H_2 \quad (2)$$

We can see that hydrogen (H_2) gas shall be released as a result of the corrosion of iron occurring according to equation (2). However, the corrosion of iron can occur according to equation (2) only if there is no oxygen in the repository. Therefore, this so-called anaerobic corrosion will commence only after the aerobic corrosion (occurring according to equation (1)) or another reaction that uses oxygen, such as microbial decay, will use up oxygen present in the repository after its closure *(Gas Related ..., 2001)*.

Solid radioactive waste to be disposed off shall also contain aluminium. As the vaults of the near-surface repository will contain huge amounts of concrete, water coming into contact with aluminium shall be alkaline. Aluminium is not thermodynamically stable in water; however, it has a very dense protective oxide layer. This oxide layer will nevertheless be dissolved in the alkaline medium, and then the following reactions that release hydrogen gas shall be possible *(Hoglund and Bengtsson, 1991)*:

$$2Al + 2OH^- + 4H_2O \text{ -------------> } 2AlO(OH)_2^- + 3H_2 \quad (3)$$

$$2Al + 2OH^- + 2H_2O \text{ -------------> } 2AlO_2^- + 3H_2 \quad (4)$$

The values of the iron and steel corrosion rate shall range from 0.1 to 10 µm annually (*Gas Related ..., 2001)*. The assessment of the formation of gas assumed the iron and steel corrosion rate to be 1 µm annually, which is equivalent to approximately 3 l/m^2 per year for the formation of hydrogen gas and for the full corrosion of 5 mm-thick steel plate during

2500 years. The value of the aluminium and zinc corrosion rate was assumed to be 0.1 mm annually, which is equivalent to the full corrosion of these metals contained in the waste during less than 100 years. The European Commission report on gas dispersion and diphase flows in a geological repository provides the review of research and experimental data in this field published prior to 1999 *(Rodwell et al., 1999)*. Gathered data on the rate of gas formation pertaining to various substances and media correspond to the rates of gas formation assumed in the evaluations performed in this report.

The evaluations of the formation of gas resulting from the corrosion of metals assume that all corroding parts (except for the carcass rods of the reinforced concrete casks) are plane. The evaluation of the corrosion rate of the carcass rods of the reinforced concrete casks assumes that the exterior surface of the rods shall continuously decrease(such decrease is a time function).

It is conservatively assumed that water enters packages immediately after the closure of the repository, as packages are not hermetic. It is assumed that gas can freely escape through gaps on the top of packages. Furthermore, it must be emphasised that it is assumed that water is not a restricting factor for the formation of gas, if water enters radioactive waste packages. It is so because the amount of water required for the formation of gas during the corrosion of metals is very small. Approximately one litre of water is required for the formation of one cubic metre of gas *(Gas Related ..., 2001)*.

Organic substances can be classified into two groups, viz. substances containing cellulose (paper, rags, cotton, timber) and other substances (plastic, rubber). The surface and volume ratio of cellulose substances is large, while the surface and volume ratio of plastics and rubbers is small. The form of organic substances, also the surface area accessible for microbial attack has a big influence on the rate of decay. The chemical medium greatly influences the microbial decay of cellulose, as the optimal conditions for the majority of microorganisms are achieved when the pH value becomes close to neutral, the temperature is approximately 25-30°C, and there are no biotoxic substances. However, various microorganisms can easily adapt to different conditions; therefore, there is a possibility that microbial activities and the release of gas will occur even though the closure of the repository and the entry of water into waste packages would result in clearly alkaline conditions. Oxygen will be used for the microbial decay of cellulose under aerobic conditions, and carbon dioxide will be produced. The corrosion of metals contained in the repository will also use oxygen. During these processes the rather small amount of oxygen present in the repository after its closure is likely to be used up within a short period of time, and anaerobic conditions will settle in the repository.

Under anaerobic conditions, other oxidising agents, such as nitrates, sulphates and carbon dioxide, will participate in the microbial decay process of cellulose. A simplified formula of the microbial decay of cellulose under anaerobic conditions can be written down as follows *(Long Term Behaviour ..., 2004)*:

$$C_6H_{12}O_6 \text{ -----------------------}> 3CO_2 + 3CH_4 \qquad (5)$$

Formula (5) shows that carbon dioxide and methane gas is released during the microbial decay of cellulose under anaerobic conditions. A more general simplified formula suitable for all organic components (including plastics and rubbers) shall be as follows *(Gas Related ..., 2001)*:

$$C_{org} + \text{Oxidising agent ----------}> C^*_{org} + H_2 + CO_2 + CH_4 + \text{Reducing agent} \quad (6)$$

Experiments performed in England *(Pedersen, 2001)* demonstrated that the production of gas after the initial formation period decreases. Pedersen emphasises that even though conditions for the microbial decay of organic substances shall not be ideal in the near-surface repository; however, even as high pH value as 12 is not an obstacle for the microbial decay process. In a Lithuanian near-surface repository, the microbial decay may be restricted because of the lack of oxidising agents and nutritional substances. Furthermore, the fact that some microorganisms can use hydrogen gas as a source of energy, thus reducing the amount of hydrogen gas released as a result of the corrosion of metals, is a possible favourable factor that reduces the general formation of gas in the repository.

It is assumed that during the microbial decay under anaerobic conditions cellulose will completely decay within less than 200 years, which conditions the annual rate of decay of 0.2 mol/kg and the annual rate of gas formation of 2 l/kg, assuming that 50% gas will be inert gas (*(Gas Related ..., 2001)*. The results of the assessment of the formation of gas in a near-surface radioactive waste repository are presented in Table 4.3.3.1.

Table 4.3.3.1. The formation of gas in a near-surface repository as a result of the corrosion of metals and the microbial decay of organic substances

	Steel	**Al + Zn**	**Organic substances**
Amount of substances in the repository	$16\ 10^6$	$2\ 10^5$	$5\ 10^5$
Rate of formation of gas, Nm^3/year	$3.2\ 10^3$	$2.8\ 10^3$	$1.1\ 10^3$
Volume of gas accumulated in the repository, Nm^3	$8\ 10^6$	$2.5\ 10^5$	$2.1\ 10^5$

Conservative assumption results presented in Table 4.3.3.1 demonstrate that rather large quantities of hydrogen, carbon dioxide and methane gas (the total volume exceeding 8 million Nm^3) may be released from components of organic substances and metal contained in the closed near-surface radioactive waste repository under anaerobic conditions. However, only 6,000 Nm^3 of hydrogen gas and approximately 500 Nm^3 of methane gas can be released annually, and these released quantities are significantly below the critical rate of inflow required for causing a fire or an explosion *(Long Term Behaviour ..., 2004)*. As made assumption are extremely conservative, it could be stated that there is only a very slight possibility that significant concentration of flammable hydrogen and methane gas are formed on the surface of the repository. Thus, the release of hydrogen and methane gas from the near-surface repository does not pose any real fire or explosion threat for the biosphere. The assessment of the release of gas and the potential consequences will be reviewed during the detail design of the near-surface repository and the safety analysis report.

While assessing the radiological impact that the release of gas has on population and environment, TECDOC-1397 of the IAEA *(Long Term Behaviour ..., 2004)* assessed a possible migration of ^3H and ^{14}C from the near-surface repository related to the release of hydrogen, carbon dioxide and methane gas. Conservative calculations of the maximum authorised annual dose for a person residing near the repository in a small house with bad ventilation have been performed, and its has been stated that radiological consequences of the disposal of radioactive waste containing ^3H and ^{14}C were very low. Analogical assessments pertaining to the amounts of gas released in our case show that the annual population exposure dose resulting from gas released from the near-surface deposit would be even less, i.e. approximately $5.7 - 10^{-3}$ mSv, and thus would not change any annual population exposure doses provided in Chapter 4.3.2.

Emergency situations and related potential atmospheric pollution are analysed in Chapter 7 *Emergency Situations*.

4.3.4. Soil

No direct soil pollution with radioactive materials is expected, if the repository is normally operated; therefore, it is not analysed by the EIA report (a potential carrying of radionuclides from the aquatic ecosystem to the terrestrial ecosystem is analysed in Chapter 4.3.2). Emergency situations and related potential soil pollution are analysed in Chapter 7 *Emergency Situations*.

4.3.5. Underground

No direct radioactive impact on the underground (geological) components is expected (the impact on water resources is analysed in Chapter 4.3.2); therefore the radioactive impact on the underground should not be analysed by the EIA report.

5. ANALYSIS OF ALTERNATIVES

This section presents the analysis of the territorial alternatives of the planned economic activities; and it also analyses the so-called "zero" alternative when short-lived low and intermediate level radioactive waste is not being disposed off.

During the analysis of the so-called "zero" alternative it must be first of all stated that in the long-term outlook the safety of solid radioactive waste storage facilities in the Ignalina NPP will become insufficient. The discharge of radionuclides from storage facilities may occur in the foreseeable future. Waste must be retrieved from storage facilities and disposed off. Therefore, the delay of the construction of the repository and the retrieval of waste is not acceptable as far as people and environment protection are concerned. The delay is economically unjustifiable as well: the failure to construct a near-surface repository may result in approximately LTL 100 million of additional costs for the storage of radioactive waste in 2011-2030, while the hypothetical income generated by the site with the area of 40 ha (required for the construction of the repository) may vary from LTL 0.4 million (traditional agriculture) to LTL 8.6 million (hypothetic intensive herb cultivation), i.e. approximately 12 to 250 times lower.

Table 5.1. Comparison of characteristics of the sites

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
Administrative jurisdiction	Rimšė neighbourhood, Ignalina region. Frontier zone. Distance to the border: approximately 3 km.	Rimšė neighbourhood, Ignalina region. Frontier zone. Distance to the border: approximately 1 km.	Territory of Visaginas City Municipality. Frontier zone. Distance to the border: approximately 4 km.
Land use and landholding system	Part of the land is agricultural, the remaining is state forest land (the forest has been recently planted).	Agricultural.	State forest land that has the status of Class 3 protective forest. Land user: State Enterprise Ignalina Nuclear Power Plant.
Distance to the Ignalina NPP	By taking the shortest road: approximately 9 km (the majority of roads are not asphalted).	4 km by direct line; approximately 5 km by road (the majority of roads are not asphalted).	The site is adjacent to the Ignalina NPP. It is separated from the territory of the Ignalina NPP by a road.
Roads	There are no suitable motorways. The distance to the railway is 2 km.	There are no suitable motorways. The distance to the railway is 2 km.	The area is circled by roads. Distance to the railway is approximately 1 km.
Existing infrastructure	There are no water supply, water purification or power supply equipment in the site. High-tension power transmission lines must be installed.	There are no water supply or water purification equipment. Approx. 1 km long 110 kV power line must be transferred.	Heat supply, water supply and power supply systems run near the site. The distance to the Visaginas treatment plant: 1 km
Relief	A hill of a complicated shape, stretching from the east to the west for about 600 m, with the width of approximately 400 m. The relative height of hills reaches 16-20 m. Peaks of the hill are in the absolute height of 161-165 m.	A ridged hill, stretching from the northwest to the southeast for about 1.2 km, with the width of 0.2-0.4 km, the relative height: 6-21 m, and the absolute height: 152-164 m.	The site has three hills with a small area. Neither area of the hills is enough for the planned repository; therefore, it is proposed to construct the repository on two hills (the western and the middle hill).

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
	Slopes of hills are of an average or high steepness.	Slopes of hills are of an average steepness. There is no danger of slope instability.	Slopes of hills are of an average steepness. There is no danger of slope instability.
	The inclination and the difference of heights create conditions for the surface run-off of water.	The prevailing inclination creates extremely favourable conditions for the surface run-off of water.	Inclinations do not create sufficient conditions for the surface run-off of water.
	The complicated shape of the hill may encumber the design and construction of the repository.	The simple shape of the hill prompts a simple architecture of the repository: the vaults of the repository may be situated in two lines.	The relief of the site is particularly hilly: there are several oblong low hills separated by descents part of which is swampy.
Geological composition	The geological profile of the site is changeable; the surface is composed of dense stable glacial loam and till with streaks of sand.	The site has the least changeable geological profile of the surface and covers a moraine flat hill (height: 10-15 m), which is composed (up to 30 m in depth) of non aquified semi-hard glacial loam, excluding sand streaks.	Both hills are similar as far as geological composition is concerned: the geological profile is changeable; the surface is composed of dense stable glacial loam and till. Dusty, sandy and clayey soils occur under a thick moraine thickening.
	The sites are characterised by stable soil of high density, which guarantees the stability of structures.	The sites are characterised by stable soil of high density, which guarantees the stability of structures.	The sites are characterised by stable soil of high density, which guarantees the stability of structures.
	No geological processes take place in the territory of the sites.	No geological processes take place in the territory of the sites.	No geological processes take place in the territory of the sites.
	There are no solid mineral resources or valuable protected geological objects in the sites.	There are no solid mineral resources or valuable protected geological objects in the sites.	There are no solid mineral resources or valuable protected geological objects in the sites.
	The thickness of the aquitard exceeds 3 m. The upper-middle Devonian aquiferous complex that is being used is protected or relatively protected from surface pollution.	The thickness of the aquitard exceeds 30 m. Confined underground water is protected from surface pollution.	Confined underground drinking water that is being used is well-protected from surface pollution. The site is in the territory of a potential complex pollution.
Hydrological and hydrogeological conditions	All three sites are in the basin of lake Drūkšiai.	All three sites are in the basin of lake Drūkšiai. However, groundwater is discharged to the Daugava river instead of lake Drūkšiai.	All three sites are in the basin of lake Drūkšiai.
	The site is located near a large lake of Apvardai. Sloping land reclamation canals predetermine a rather fast flow of surface water and its high dilution.	The site is near a large lake of Drūkšiai (at a distance of 0.7 km). Tributaries of lake Drūkšiai and sloping land reclamation canals predetermine a fast flow of surface water and its high dilution.	The site is approximately 2 km away from lake Drūkšiai.

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
	The hydrological regime of the site has been reorganised during the installation of the land reclamation system.	The hydrological regime of the site has been reorganised during the installation of the land reclamation system.	The hydrological condition of the site has been affected. Seasonal or permanent water bodies have been formed in descents.
	The probability of flooding of the site is low.	The probability of flooding of the site is nil.	The probability of flooding of the site is nil.
	The groundwater level is close to the surface of the site. The prevailing transfer of water is towards the aquifer occurring in the depth of approximately 3.5 m. The thickness of the aquifer is approximately 2 m.	The prevailing transfer of water is towards the semi-confined-confined aquifer occurring in the depth of approximately 30 m. The thickness of the aquifer is approximately 10 m.	The level of groundwater (present in places) is high. The transfer of water is complicated. The thickness of the middle aquifer is approximately 19 m.
	The hydrogeological condition of the Apvardai site is more complicated than that of the Galilaukė site, while the level of water is higher.	The site is the most suitable from the hydrogeological point of view.	The hydrogeological situation of the Stabatiškė site is more complicated than that of the Galilaukė site. Even though there is no danger of flooding of the foundation of the repository, an efficient drainage system is required.
Biodiversity, protected areas and ecological networks	There are no valuable types of flora that any protective measures should be taken to preserve them. No special measures for the protection of biodiversity are required.	There are no valuable types of flora that any protective measures should be taken to preserve them. No special measures for the protection of biodiversity are required.	Protected amphibia have been found near the site. They should be transferred to other suitable places prior to commencing any work.
	There are no protected areas or ecological networks in the sites, and water protection zones are not affected.	There are no protected areas or ecological networks in the sites, and water protection zones are not affected.	There are no protected areas or ecological networks in the sites, and water protection zones are not affected.
Cultural heritage treasures	There are no heritage treasures.	There are no heritage treasures.	The site of the Stabatiškė estate (village) may be destroyed. Proposed methods to reduce the impact: 1. To reduce the built on area and not to affect the site of the estate during construction. In this case the hills will no longer have any area for the expansion of the repository. 2. To perform the complete scientific and archaeological study of the site of the Stabatiškė estate (village).

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
Socioeconomic environment	There are no homesteads in the site. There are several settlements in the neighbourhood. Agriculture similar to subsistence farming prevails in the vicinity of the site. Local natural resources are used only for the subsistence bioproduction farming and for low-intensity recreation; in the neighbourhood of the site, material investments are used only for the management of homesteads.	There is one homestead in the site and few small settlements in the vicinity. Agriculture similar to subsistence farming prevails; local natural resources are used only for the subsistence bioproduction farming. Either the sole homestead should be moved or special protection measures should be taken.	Presently, there are no residents in the site or in the vicinity, as they were moved during the construction of the Ignalina NPP.
	The site is more reclaimed, technogenised and more easily accessible than the Galilaukė site. This site is characterised by a higher potential for organic large farms, and it has more appurtenances of the landholding system. Therefore, there is a higher probability of conflicts of interests in the site involving landowners and land users.	The site is less reclaimed and the access is more difficult. The site is characterised by less potential for organic large farms, and it has less appurtenances of the landholding system; thus, there is a lower probability of conflicts of interests in the site involving landowners and land users.	The objective of farming in forests of Class 3: to form protective stands which can perform the functions of environment protection.
Public opinion and opinion of the Council of Ignalina Municipality	The site should not be considered.	Out of the considered alternatives of the Apvardai site and the Galilaukė site, the Galilaukė site is a more acceptable option. Compensations are required.	-
Public opinion and opinion of Visaginas Municipality	-	-	Agree.
Hazardous installations	There are no hazardous industrial facilities in the vicinity of the sites, except for the Ignalina NPP itself. The nearest operating military aerodrome is approximately 50 km away in Belarus. The nearest civil aerodrome (hardly ever used) is in Zarasai, at a distance of approximately 30 km.	There are no hazardous industrial facilities in the vicinity of the sites, except for the Ignalina NPP itself. The nearest operating military aerodrome is approximately 50 km away in Belarus. The nearest civil aerodrome (hardly ever used) is in Zarasai, at a distance of approximately 30 km.	There are no hazardous industrial facilities in the vicinity of the sites, except for the Ignalina NPP itself. The nearest operating military aerodrome is approximately 50 km away in Belarus. The nearest civil aerodrome (hardly ever used) is in Zarasai, at a distance of approximately 30 km.

Aspect	Apvardai site	Galilaukė site	Stabatiškė site
Safety assessment	The assessed annual maximum population exposure dose is 9 10^{-3} mSv, under the normal evolution scenario. The exemption level is not exceeded.	The assessed annual maximum population exposure dose is 0.41 10^{-3} mSv, under the normal evolution scenario. The exemption level is not exceeded.	The assessed annual maximum population exposure dose is 9 10^{-3} mSv, under the normal evolution scenario. The exemption level is not exceeded.

* - In order to demonstrate that the Stabatiškė site has sufficient area for the vaults of the repository, a reference scheme of a potential layout of the repository has been developed (*RATA, 2005*). Based on the said layout, the simulation of radionuclide migration has been performed. The western hill and the nearby middle hill are the best suited area for the construction of the repository in Stabatiškė village (*A. Rimidis, 2005*). The surrounding areas are too wet; there are open water bodies formed as a result of works performed during the construction of the power plant; therefore, drainage should be performed in the construction zone. Hills should have to be lowered, and a multilayer drainage should have to be constructed using natural filtering substances, such as coarse-grained sand, gravel and broken granite, for the protection of the foundation of the radioactive waste repository from groundwater.

Having summarised data provided in Table 5.1, a conclusion may be drawn that all three analysed sites meet the general safety requirements and are basically suitable for the construction of a near-surface repository. Any further analysis of the Apvardai site is impeded by several important factors, such as unfavourable social environment, unfavourable public opinion, not completely favourable natural (geological, hydrogeological, etc.) conditions. Therefore, this site should be rejected.

The Galilaukė site has very favourable natural conditions; the social environment is more favourable as well as well. It has very favourable conditions for performing construction works. Resolution No. T-403 of the Council of Ignalina Region Municipality dated 21 December 2004 states that "*out of two construction sites presented in the EIA report, the territory of Galilaukė is more acceptable*". The Council of Ignalina Region Municipality inadequately assesses the potential construction of the repository and indicates the necessity of compensations. Belarus categorically opposes the Galilaukė site.

The natural conditions of the Stabatiškė site are not very favourable for construction. It is a small site; therefore, the repository could not be further expanded in future. Furthermore, this site is near other facilities and sites visited by people; therefore, the collective exposure dose would be slightly higher. The detected site of the Stabatiškė estate (village) may be destroyed as a result of the construction of the repository. The following alternatives to reduce the impact have been proposed: either to reduce the built on area and not to affect the site of the estate during construction, or to perform the complete scientific and archaeological study of the site of the Stabatiškė estate (village). In the latter case, the study would cover the area of 0.6 ha, and this would cost an addition LTL 1.5 million (*Dėl Stabatiškės..., 2006*).

The obvious advantage of the Stabatiškė site is the infrastructure, favourable social conditions and a very close proximity to the producer of waste (the nuclear power plant). As the site is near the producer of waste, some of the waste acceptance procedures could be optimised and certain auxiliary structures (e.g. interim storage facility in the territory of the repository) may not be required. The Stabatiškė site is in the so-called "nuclear" territory used by the Ignalina NPP. It is further away than other sites from the state border. The possibility to construct a near-surface repository in this site has been positively assessed and consented to by the community of residents and the administration of Visaginas Municipality.

Therefore, the Stabatiškė and the Galilaukė sites should be further considered as potential alternatives.

6. ENVIRONMENTAL MONITORING: MONITORING PROGRAMME

This outline of the environmental monitoring programme presented in this chapter is basically suitable for all three candidate sites. In each of the sites the same goals and organisational principles will apply, the same meteorological and hydrological monitoring and measurement will be performed, samples for the analysis of the same type will be taken, etc. Only the location and number of monitoring points/stations will differ. It will be adjusted after the detail design of the repository is developed. The final version of the monitoring programme will analyse the need for the monitoring of the environment in neighbouring countries.

6.1. General

Goals

Systematic environmental monitoring shall be performed to achieve the following goals:

1) to assure that personnel and population exposure doses do not exceed the established threshold doses;

2) to inspect whether the operation regime of the near-surface radioactive waste repository is as designed, and to warn about any deviations;

3) to inform the society about any increased environmental pollution (the discharge of radionuclides from the repository);

4) to obtain data required for the assessment of exposure doses, either conditioned by the repository or potential;

5) to identify the input of the repository into environmental pollution, and to distinguish it from the impact of other sources of pollution.

Monitoring must be effective both under normal operation of the repository and in radiological emergencies.

Organisational principles

Pursuant to legislation regulating environmental monitoring, economic operators must perform radiological monitoring (consisting of monitoring of pollution and environmental monitoring) in each nuclear energy installation. The development of the monitoring programme must consider the expected environmental pollution and the environmental and demographic peculiarities of the installation, as well as the chemical or physical form and composition of polluting substances.

To assess the “background” pollution (natural, globally outspread radionuclides and radionuclides from other sources of pollution), environmental monitoring will commence at least one year earlier than the start of activities, and will continue uninterruptedly all through the disposal of waste (operation of the repository) and after the closure of the repository (during active surveillance). The monitoring programme must cover all important radionuclide migration and population exposure routes. Sufficient data must be collected during the implementation of the programme to enable the assessment of the annual activity of run-off, its short-term changes, and doses for members of critical groups.

Monitoring will be performed by applying such methods of measurement and using such devices that would allow a rather precise measuring of radionuclide activities of isolated isotopes that may determine annual dozes exceeding 0.005 mSv. The sampling frequency of environmental components corresponds to the change of environmental components, while the obtained data must be sufficient to assess the exposure of people of the critical group/groups. Run-off radionuclide activities must be reliably assessed under the conditions of the short-term increase of pollution. If the expected environmental pollution is higher than usual, additional monitoring of pollution must be performed. Sampling may be more frequent than provided by this programme, and additional measuring may be performed, if run-off activity or composition is known or expected to change.

The first review (revision) of this programme shall be performed one year after the start of activities (operation of the repository), and every five years afterwards. Reviews shall take account of the accumulated experience and all new methods and measures of monitoring, also changes in the condition of the repository, environment conditions and demographic changes. The monitoring programme may also be revised during the design of the repository, while performing the safety analysis or after data on waste to be disposed of are revised; it may become clear that this programme pays not sufficient attention to certain migration routes of radionuclides, while other routes are not important and their monitoring is inexpedient. The monitoring programme of the repository will be fundamentally reviewed during the closure of the repository and the commencement of the post-closure surveillance. Amendments of the monitoring programme shall be co-ordinated with the Ministry of Environment.

List of normative documents

This programme has been developed in compliance with the following legislation:

1. Lietuvos Respublikos aplinkos apsaugos įstatymas (Žin., 1992, Nr. 5-75; 1996, Nr.57-1335; Nr.65-1540; 2000, Nr.39-1093; 2000, Nr.90-2773; 2002, Nr. 2-49; 2003, Nr. 61-2763; 2004, Nr. 36-1179; 2004, Nr. 60-2121) = *Law of the Republic of Lithuania on Environmental Protection (Official Gazette,* No. 5-75, 1992; No. 57-1335, 1996; No. 65-1540; No. 39-1093, 2000; No. 90-2773, 2000; No. 2-49, 2002; No. 61-2763, 2003; No. 36-1179, 2004; No. 60-2121, 2004) (*in Lithuanian*);

2. Lietuvos Respublikos aplinkos monitoringo įstatymas (Žin., 2006, Nr. 57-2025) = *Law of the Republic of Lithuania on Environmental Monitoring* (*Official Gazette*, No. 57-2025, 2006) (*in Lithuanian*);

3. Lietuvos Respublikos branduolinės energijos įstatymas (Žin., 1996, Nr.119-2771; 1999, Nr. 65-2088) = *Law of the Republic of Lithuania on Nuclear Energy* (*Official Gazette*, No. 119-2771, 1996; No. 65-2088, 1999) (*in Lithuanian*);

4. Lietuvos Respublikos radiacinės saugos įstatymas (Žin., 1999, Nr. 11-239) = *Law of the Republic of Lithuania on Radiation Protection* (*Official Gazette*, No. 11-239, 1999) (*in Lithuanian*);

5. Normatyvinis dokumentas LAND 42 - 2001 „Radionuklidų išmetimo į aplinką iš branduolinės energetikos objektų ribojimas ir radionuklidų išmetimo leidimų išdavimo bei radiologinio monitoringo tvarka", patvirtintas LR aplinkos ministro 2001 01 23 įsakymu Nr. 60 (Žin., 2001, Nr. 13-415) = *Normative document LAND 42-2001 "Limitation of Radioactive Discharges from Nuclear Facilities, Permitting of Discharges and Radiological Monitoring"* approved by Order No. 60 of the Minister of Environment of the Republic of Lithuania on 23 January 2001 (*Official Gazette*, No. 13-415, 2001) (*in Lithuanian*);

6. Normatyvinis dokumentas LAND 36-2000 „Aplinkos elementų užterštumo radionuklidais matavimas – mėginių gama spektrinė analizė spektrometru, turinčiu puslaidininkinį detektorių", patvirtintas LR aplinkos ministro 2000 10 16 įsakymu Nr. 417 (Žin., 2000, Nr. 101-3208) = *Normative document LAND 36-2000 "Measurement of Radionuclide Content in Environmental Components; Gamma Spectroscopic Analyse of Samples by Spectrometer with Semiconductor Detector"* approved by Order No. 417 of the Minister of Environment of the Republic of Lithuania on 16 October 2000 (*Official Gazette*, No. 101-3208, 2000) (*in Lithuanian*);

7. Normatyvinis dokumentas LAND 37-2000 „Aplinkos elementų užterštumo radionuklidais matavimas – vandenyje ištirpusio cezio radionuklidų koncentracijos

matavimas sorbuojančiaisiais filtrais ir vandens tūrinio aktyvumo įvertinimas", patvirtintas LR aplinkos ministro 2000 10 16 įsakymu Nr. 417 (Žin., 2000, Nr. 101-3208) = *Normative document LAND 37-2000 "Measurement of Radionuclide Content in Environmental Component; Concentration of Caesium Radionuclides Dissolved in Water Employing Absorbing Filters and Estimation of Water Activity Concentration"* approved by Order No. 417 of the Minister of Environment of the Republic of Lithuania on 16 October 2000 (*Official Gazette*, No. 101-3208, 2000) (*in Lithuanian*);

8. Lietuvos standartas LST ISO 9696:1998 „Vandens kokybė. Bendrojo tūrinio alfa aktyvumo matavimai mažai mineralizuotame vandenyje. Storo sluoksnio metodas" = *Lithuanian standard LST ISO 9696:1998 "Water Quality. Measurement of Gross Alpha Activity in Non-Saline Water. Thick Source Method"* (*in Lithuanian*);

9. Lietuvos standartas LST ISO 9697:1998 „Vandens kokybė. Bendrojo tūrinio beta aktyvumo matavimai mažai mineralizuotame vandenyje" = *Lithuanian standard LST ISO 9697:1998 "Water Quality. Measurement of Gross Beta Activity in Non-Saline Water"* (*in Lithuanian*);

10. Lietuvos standartas LST ISO 9698:1998 „Vandens kokybė. Tričio tūrinio aktyvumo nustatymas. Skysto scintiliatoriaus metodas" = *Lithuanian standard LST ISO 9698:1998 "Water Quality. Determination of Tritium Activity Concentration. Liquid Scintillation Counting Method"* (*in Lithuanian*);

11. Standard ISO 10703:1997 "Water quality – Determination of the activity concentration of radionuclides by high resolution gamma-ray spectrometry";

12. Standartas IEC 1452:1995 „Radionuklidų gama spinduliuotės intensyvumų matavimas. Germanio spektrometro kalibravimas ir naudojimas" = *Standard IEC 1452:1995 "Measurement of Gamma-ray Emission Rates of Radionuclides – Calibration and Use of Germanium Spectrometers"* (*in Lithuanian*);

13. LR aplinkos ministro 2003 m. 11 25 įsakymas Nr. 590 „Dėl aplinkos ministro 2002 m. vasario 27 d. įsakymo Nr. 80 „Dėl taršos integruotos prevencijos ir kontrolės leidimų išdavimo, atnaujinimo ir panaikinimo taisyklių patvirtinimo" ir dėl aplinkos ministro 1999 m. lapkričio 30 d. įsakymo Nr. 387 „Dėl aplinkos apsaugos normatyvinio dokumento LAND 32-99 „Gamtos išteklių naudojimo leidimų išdavimo ir gamtos išteklių naudojimo limitų bei leistinos taršos į aplinką normatyvų nustatymo tvarka" patvirtinimo" pakeitimo", galios iki 2009-01-01 (Žin., 2003, Nr. 114-5169) = *Order No. 590 "On the Amendment of Order No. 80* On the Approval of the Rules of the Issuance, Renewal and Annulment of Integrated Pollution Prevention and Control Approvals *of the Minister of Environment dated 27 February 2002 and Order No. 387* On the Approval of Normative Document LAND 32-99 "On Setting the Permits for Use of Natural Resources and for Setting Limits for Use of Natural Resources and Discharge of Pollutants into Environment" *of the Minister of Environment dated 30 November 1999" of the Minister of Environment of the Republic of Lithuania dated 25 November 2003*; valid until 1 January 2009 (*Official Gazette*, No. 114-5169, 2003) (*in Lithuanian*);

This programme has been developed according to */text is missing, - translator's note/* described in normative document LAND 42-2001 for establishing the procedure of the radiological monitoring of nuclear facilities. The planned radioactive waste repository has many material peculiarities; therefore, this programme features insignificant nonconformities with the said document. A different (non-radiological) impact (e.g. pollution with chemical substances) should be evaluated pursuant to the Law on Environmental Monitoring and other legislation.

6.2. Meteorological and hydrological monitoring

Meteorological and hydrological monitoring is performed in the repository area the data of which are important for the analysis of radionuclide dispersion in the repository area, the assessment of the exposure of residents of critical groups and for the verification of the compliance of the repository safety with design requirements. The results of such monitoring shall also be used for the implementation of the emergency measures and measures for the handling of extreme situations.

The following meteorological and climatologic monitoring shall be performed in the repository area:

1) air temperature measurements (daily average, maximum and minimum values);

2) precipitation measurements.

The monitoring is performed every hour in the meteorological monitoring site constructed near the repository. Where any additional meteorological data are required, data of the nearest meteorological station of Drūkšiai shall be considered.

The following hydrological monitoring shall be performed in the repository area:

1) the rate of flow of water discharged from the drainage system of the repository (measurements shall be performed on a monthly basis);

2) chemical properties of discharged water (measurements of pH and concentrations of main anions, cations and dissolved oxygen shall be performed on a monthly basis);

3) physical properties of discharged water (measurements of the temperature, electrical conductivity, concentration of suspended particles shall be performed on a monthly basis);

4) monitoring of water bodies to which wastewater is or may be discharged (lake Drūkšiai, the Drūkša river and land reclamation canals), the level of water, physicochemical properties, concentration and the sedimentation rate of suspended particles (measurements shall be performed every three months);

5) the level of water in monitored bores.

In order to obtain data over a longer period of time, after the hydrological investigations of the sites provided in the site description programme are carried out (the results are provided in section 4.1), the monitoring of groundwater and surface water levels will be continued, i.e. the monitoring of the water system will be performed until the commencement of the construction of the repository. Prior to the commencement of the design of the repository, the potential impact of new objects under construction in the vicinity of the site on the hydrological conditions of the site must be analysed.

6.3. Monitoring of pollution

There is no technical necessity to release radioactive pollutants into the environment from radioactive waste repository during its operation and surveillance. Radionuclide releases into the environment are expected to be very small; therefore, it will be difficult to exercise direct control over them (except for shower water and water used for sanitary cleaning and for the decontamination of equipment and vehicles, as it is easy to control the discharge of such water).

Radioactive waste accumulated in the Ignalina NPP will be disposed in the repository. They contain many radionuclides with different characteristics; therefore different methods of measurement will have to be applied.

Monitoring of carry-overs

Pursuant to General Eligibility Criteria of Radioactive Waste for the Disposal in a Near-Surface Repository P-2003-01 (*Official Gazette*, *No. 19-850, 2003*), radionuclides that release radioactive gas either will not be disposed in the repository or only insignificant amounts may be disposed of. Monitoring of radionuclide activities of gaseous or aerosol carry-overs is not provided for, as radionuclides will not be released from the repository into the atmosphere.

Monitoring of wastewater

During the operation of the repository, shower water and water used for sanitary cleaning and decontamination is the only pollutant of the environment that is easily controlled. Process water will be collected into the process water tank. When the tank is full, water shall be sampled for laboratory analysis (Table 6.1). If activities do not exceed the established values, analysed water will be discharged to the water treatment facility. A drainage system will be installed in the area of auxiliary structures and vaults of the repository in order to collect rainwater in the repository area. Water shall be sampled and the required analysis shall be performed on a monthly basis (Table 6.1). The amount of drained water will be established according to the amount of precipitation registered at the meteorological monitoring site.

Table 6.1. Pilot tests of process water and drained rainwater

Measurements	Sampling frequency	Measuring frequency	Means of measurement	Methods of measurement
Pilot tests of process water				
Water amount	Each time before discharging	During each discharge	The total amount of water discharged during the month shall be added up	-
Activity concentration of gamma emitters	Each time before discharging	Each time before discharging	Laboratory analysis	Gamma spectroscopic analysis: LAND 36-200 and IEC 1452:1995
Activity concentration of ^{3}H	Each time before discharging	Each time before discharging	Laboratory analysis	LST ISO 9697:1998*
Gross beta activity concentration	Each time before discharging	Each time before discharging	Laboratory analysis	LST ISO 9697:1998**
Gross alpha activity concentration	Each time before discharging	Each time before discharging	Laboratory analysis	LST ISO 9696:1998***
Activity concentration of ^{90}Sr	Each time before discharging	Every month, if water is discharged	Integral monthly test specimen	Radiochemical evolution: LAND 64-2005
Activity concentration of $^{239,240}Pu$	Each time before discharging	Every month, if water is discharged	Integral monthly test	Radiochemical evolution, alpha spectroscopic analysis
Activity concentration of ^{14}C	Each time before discharging	Once a year	Integral annual test	Liquid scintillation counting method
Pilot tests of drained rainwater				
The amount (flow) of drained water	-	-	Calculation	
Activity concentration of gamma emitters	Every month	Every month	Monthly test specimen	Gamma spectroscopic analysis: LAND 36 and

Measurements	Sampling frequency	Measuring frequency	Means of measurement	Methods of measurement
				IEC 1452:1995
Activity concentration of ^{3}H	Every month	Every month	Monthly test specimen	LST ISO 9697:1998*
Gross beta activity concentration	Every month	Every month	Monthly test specimen	LST ISO 9697:1998**
Gross alpha activity concentration	Every month	Every month	Monthly test specimen	LST ISO 9696:1998***
Activity concentration of ^{90}Sr	Every month	Every month	Monthly test specimen	Radiochemical evolution: LAND 64-2005
Activity concentration of $^{239,240}Pu$	Every month	Once a year	Integral annual test specimen	Radiochemical evolution, alpha spectroscopic analysis
Activity concentration of ^{14}C	Every month	Once a year	Integral annual test specimen	Liquid scintillation counting method

* - The method is applied to all types of water where tritium activity concentration does not exceed 10^6 Bq/m^3. The method is not employed for the measurement of tritium in organic form.

** - Test specimens are stabilised by acidification; they are evaporated and heated as sulphates at a temperature of 350°C. A part of the test specimen is placed in the measuring dish of beta detector, and beta activity of the sample is measured. The method is applied to radionuclides the maximum energy of beta particles of which exceeds 0.3 MeV.

*** - Test specimens are stabilised by acidification; they are evaporated and heated as sulphates at a temperature of 350°C. A part of the test specimen is placed in the measuring dish of alpha detector, and alpha activity of the sample is measured. The method is applied to non-volatile alpha radionuclides.

6.4. Environmental monitoring

Environmental monitoring covers measurements of activities of the dose rate of ionising radiation in the environment as well as activities of external absorbed dose and radionuclides in various environmental components. The selection of environmental objects is determined by the importance of radionuclides accumulating in these objects for the exposure of population of critical groups. Continuous measurements of ionising radiation are performed in representative spots of the repository area and near residential areas. Automatic electronic devices are used for measuring the dose rate, and dose accumulating devices (thermoluminescent dosimeters) are used for measuring the absorbed dose. Environmental object samples are taken for radioisitopic analysis at the points of discharge of drained water and other wastewater as well as in places of the highest expected contamination. The radionuclide content of samples is established (the specific activity of gamma emitters is measured) in order to assess the environmental pollution. The pollution with beta emitters (^{90}Sr, ^{3}H, ^{14}C, etc.) and alpha emitters ($^{239,\ 240}Pu$, ^{241}Am, etc.) is assessed by analysing the selected most typical samples. Methods of the chemical evolution of elements shall be applied, if required, during the measurement of the specific activity of beta and alpha emitters.

In terrestrial ecosystem, samples provided in Table 6.2 are taken or direct (*in situ*) measurements are performed. The system of “dry” and “wet” bores will be built near the vaults (without affecting the leak-tightness of the vaults) in order to identify discharges of radionuclides from the repository and to monitor the condition of barriers of the repository. The former are intended for the mobile gamma spectrometer detector, which is lowered to the foundation of the repository), and the latter – for the detection of groundwater, if it permeates from the repository. Considering the experience of other similar repositories (El Cabril in Spain or l’Aube in France), no special galleries for the collection and monitoring of permeated water will be constructed under the vaults of the repository, as they would significantly reduce the reliability and durability of the repository. It is obvious that similar systems are "active" elements that require continuous maintenance and repair. If for any unknown reason the surveillance of the repository is terminated prior to its term, these systems will inevitably disintegrate, and this may have rather significant consequences.

Table 6.2. Samples taken and measurements performed in terrestrial ecosystem

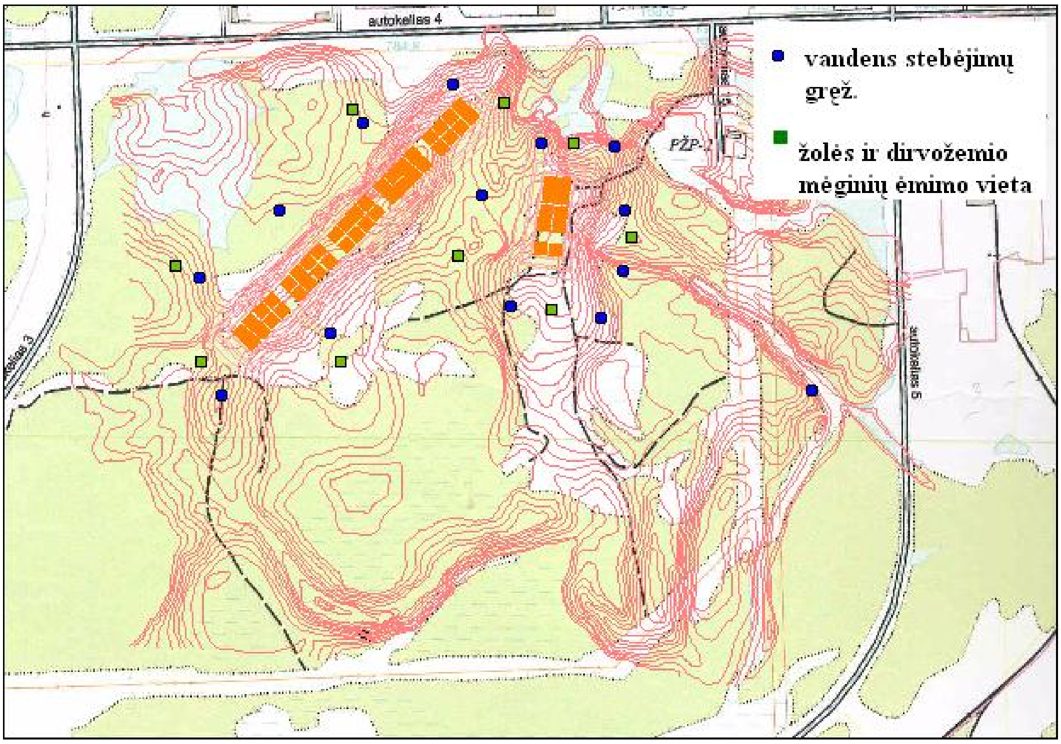
	Component of the environment	**Number of monitoring points/stations**	**Sampling frequency**	**Measuring mean and method**	**Measured parameters**	**Units**
1	Soil	16 points (Fig. 6.2) in the Galilaukė site	Once a year	Gamma spectroscopic analysis LAND 36-2000, IEC 1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis	Specific activity of gamma emitters, once a year Specific activity of Pu, every 5 years	Bq/kg of dry matter and Bq/m^2
2	Earth (in the level of the foundations of repository vaults)	25 "dry" bores (Fig. 6.2)	Once a quarter	Direct (*in situ*) gamma spectroscopic analysis	Identification of gamma emitters	-
3	Underground water (groundwater) (from monitoring bores or wells)	25 bores in the repository area, 8 bores in the vicinity of the repository, one shaft-well (Fig. 6.1). The layout of bores in the repository area will be developed after the detail design of the repository is developed.	Once a quarter	Gamma spectroscopic analysis: LAND 36-2000, IEC 1452:1995; Activity concentration of ^3H: LST ISO 9698:1998 Gross beta activity concentration: LST ISO 9697:1998 Gross alpha activity concentration: LST ISO 9696:1998 Specific activity of ^{14}C	Activity concentration of gamma emitters: once a quarter Activity concentration of 3H: once a quarter Gross beta activity concentration: once a quarter Gross alpha activity concentration: once a quarter Specific activity: once a year	Bq/m^3
3	Sludge resulting from domestic wastewater treatment	One place	Every month	Gamma spectroscopic analysis: LAND 36-2000, IEC 1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis	Specific activity of gamma emitters: once a month Specific activity of Pu, every 3 months	Bq/kg of dry matter
4	Pasture grass, grass of water-meadows and	Five in the Galilaukė site: One at the	Once a year, at the end of summer	Gamma spectroscopic analysis:	Specific activity of gamma emitters	Bq/kg of wet matter

	Component of the environment	Number of monitoring points/stations	Sampling frequency	Measuring mean and method	Measured parameters	Units
	swamps	entrance, one at the southern slope, one at the northern slope, one near the homestead and one towards the Drūkšta river (Fig. 6.3). Eight in the Stabatiškė site (Fig. 6.1)		LAND 36-2000 IEC 1452:1995		
	Goat's (or cow's) milk*/***	One reference animal group pasturing in the repository area	Once a quarter during the warm season	Gamma spectroscopic analysis of integral samples of three months: LAND 36-2000, IEC 1452:1995 Radioisitopic evolution of ^{90}Sr and measurement of ^{90}Y	Activity concentration of gamma emitters Activity concentration of ^{90}Sr	Bq/L
6	Goat's meat (or meat of other animals or birds*)***	One reference animal group pasturing in the repository area	Once a quarter during the warm season	Gamma spectroscopic analysis: LAND 36-2000 IEC 1452:1995	Specific activity of gamma emitters	Bq/kg of wet matter
7	Gamma dose rate	3 stationary stations (Fig. 6.4) in the Galilaukė site. 5 stationary stations (Fig. 6.2) in the Stabatiškė site. Approximately 30 monitoring points (Fig. 6.4) in the Galilaukė site. **Approximately 40 monitoring points (Fig. 6.2) in the Stabatiškė site.**	Continuous measuring and indication Every 3 months, using portable dosimeter.	*In situ* measurements	Gamma dose rate	μSv/h
8	External absorbed dose	18 TLD** (Fig. 6.4) in the Galilaukė site. 17 TLD** (Fig. 6.2) in the Stabatiškė site.	Continuous accumulation; data are registered once a quarter	*In situ* measurements	External absorbed dose	mSv

* - As cow's milk and beef are among the most important food products in Lithuania, they should be monitored; however, the results would cause much doubt because of a very small number of reference animals. Therefore, it is more rational to monitor smaller animals (e.g. goats bred especially for monitoring).

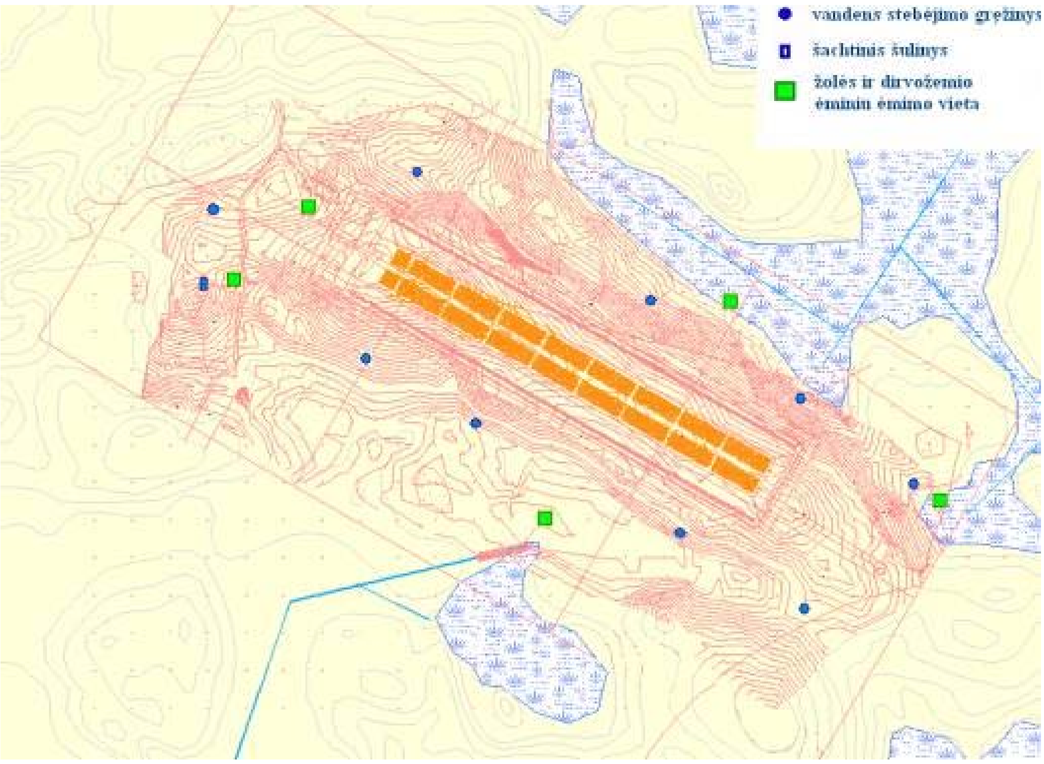
** - TLD are distributed in the repository area, near transportation roads, towards residential places and in places most frequently visited by people.

*** - This type of analysis may not be performed in the Stabatiškė site, if the site has no conditions for pasturing cattle.



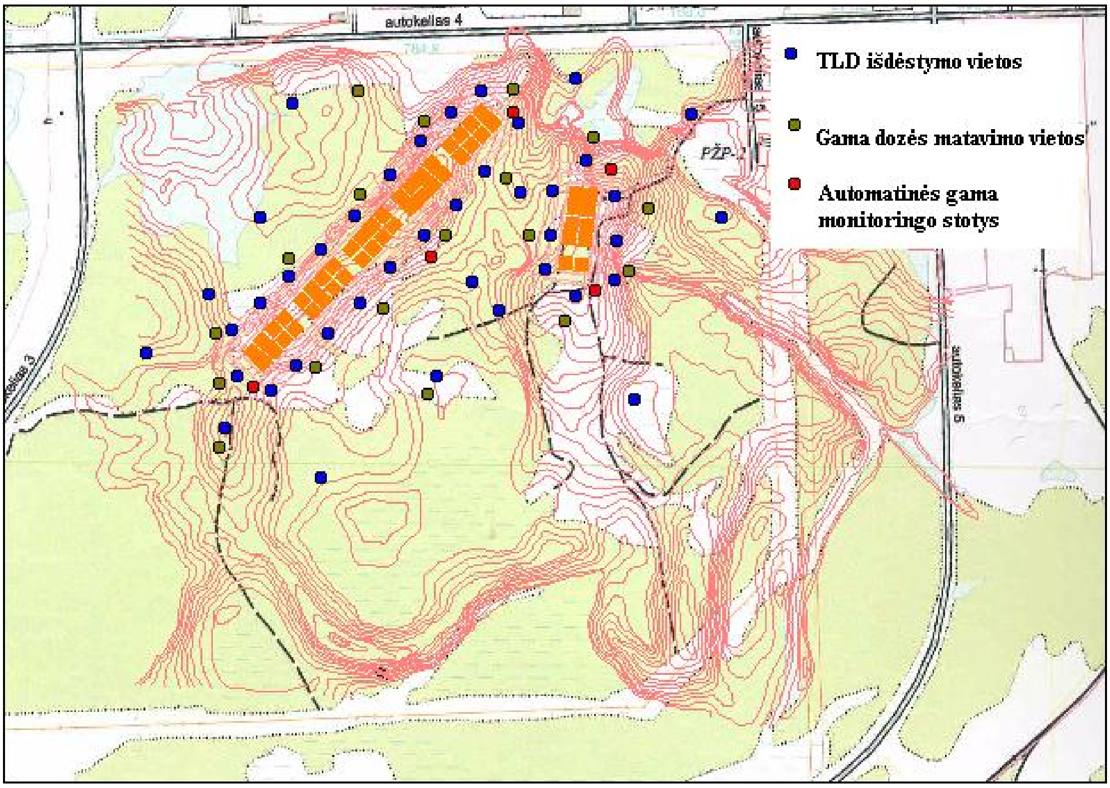
vandens stebėjimų gręž.	Water monitoring bores
žolės ir dirvožemio mėginių ėmimo vieta	Grass and soil sampling location

Fig. 6.1 Locations of sampling of components of terrestrial ecosystem in the vicinity of the repository – the Stabatiškė site.



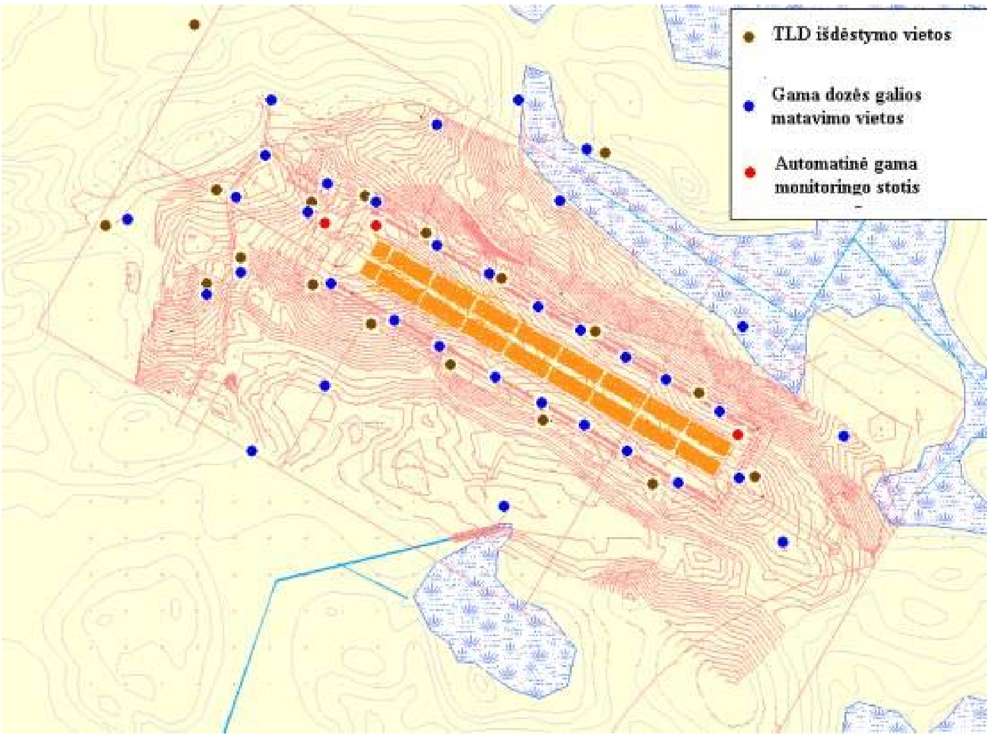
vandens stebėjimo gręžinys	Water monitoring bore
šachtinis šulinys	Shaft-well
žolės ir dirvožemio ėminių ėmimo vieta	Grass and soil sampling location

Fig. 6.2 Locations of sampling of components of terrestrial ecosystem in the vicinity of the repository – the Galilaukė site.



TLD išdėstymo vietos	Location of TLD
Gama dozės matavimo vietos	Gamma dose measuring points
Automatinės gama monitoringo stotys	Automatic gamma monitoring stations

Fig. 6.3 Location of thermoluminescent dosimeters and points for the measuring of gamma dose rate in the Stabatiškė site



TLD išdėstymo vietos	Location of TLD
Gama dozės galios matavimo vietos	Gamma dose rate measuring points
Automatinė gama monitoringo stotis	Automatic gamma monitoring station

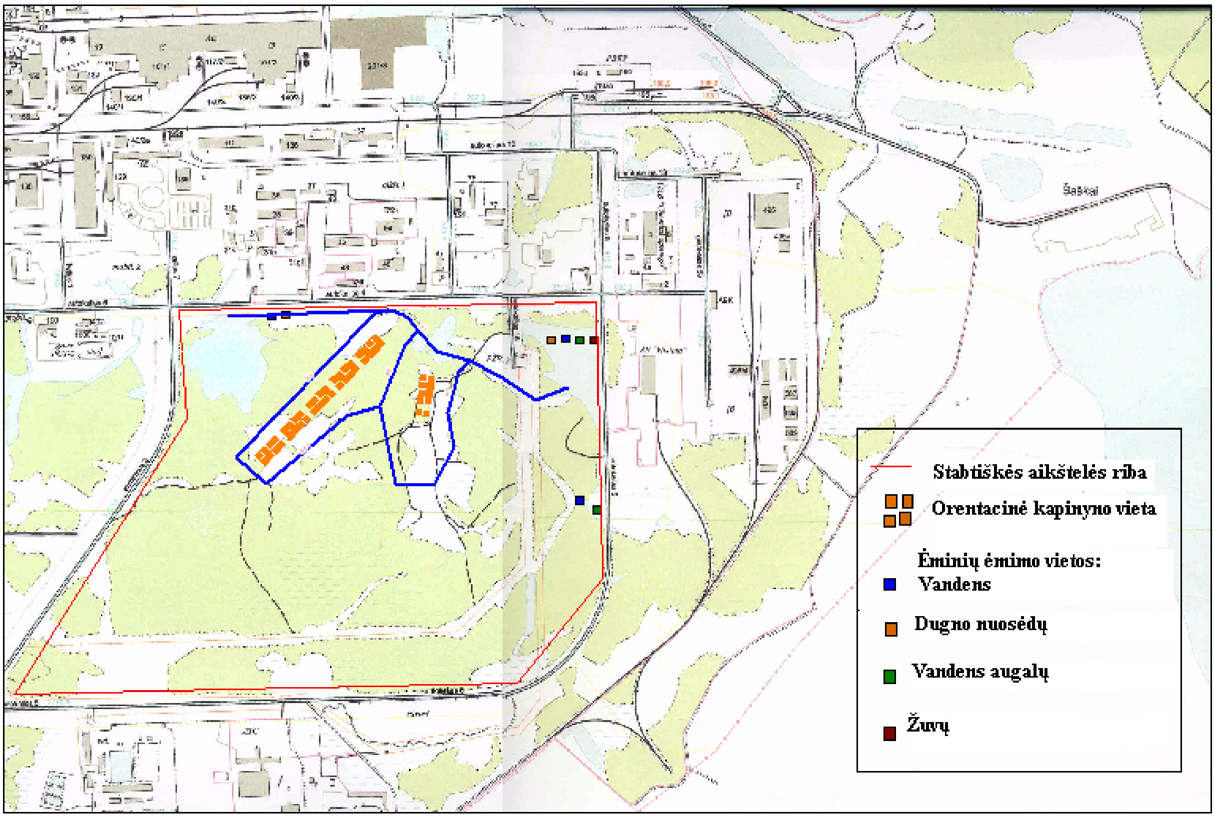
Fig. 6.4 Location of thermoluminescent dosimeters and points for the measuring of gamma dose rate in the Galilaukė site

In aquatic ecosystem, samples provided in Table 6.3 are taken. Locations of sampling are shown in Fig. 6.5 and 6.6.

Table 6.3. Samples taken and measurements performed in aquatic ecosystem

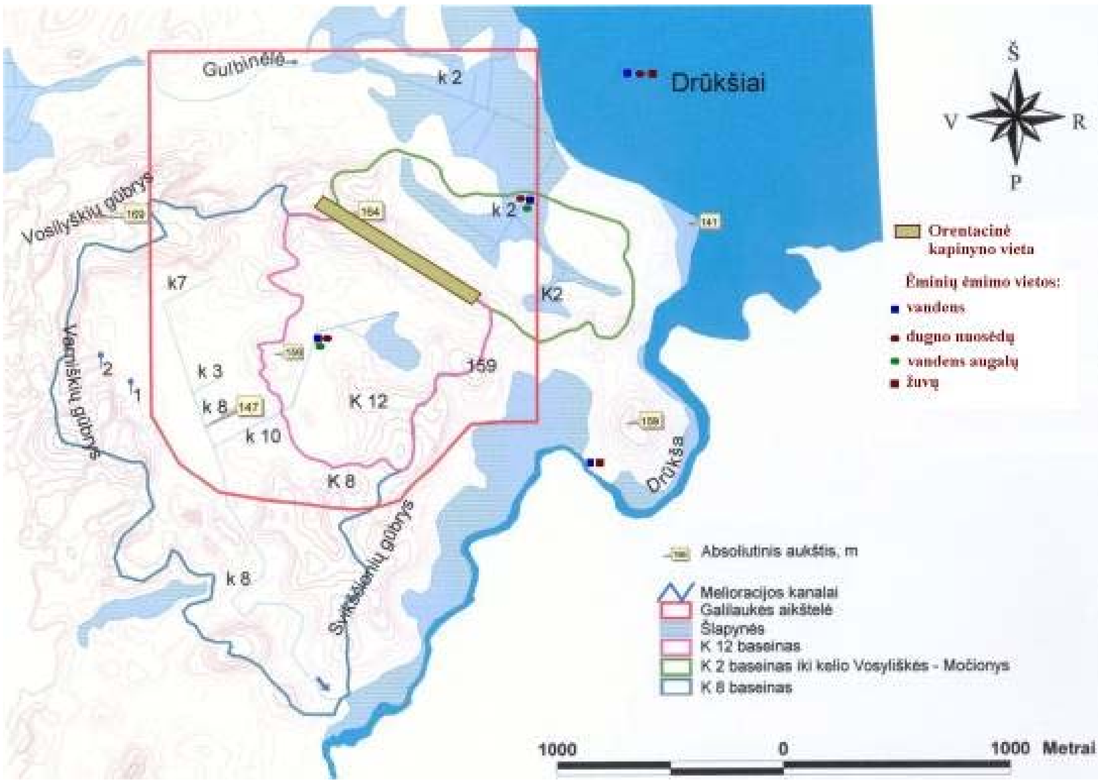
	Component of the environment	Number of monitoring points/stations	Sampling and measuring frequency	Means of measurement	Measured parameters	Units
1	Water	Six in the Galilaukė site: two land reclamation ditches, the Drūkšta river and lake Drūkšiai. **Two in the Stabatiškė site: one in water bodies located in the territory of the site and one in the land reclamation canal.**	Once a quarter	Gama spectroscopic analysis of filtered non-concentrated water samples (LAND 36-2000, LAND 37-2000, IEC 1452:1995) Specific activity of ^{3}H: LST ISO 9698:1998 Gross beta specific activity: LST ISO 9697:1998 Gross alpha specific activity: LST ISO 9696:1998 Specific activity of ^{14}C using liquid scintillation counting method	Activity concentration of ^{3}H, ^{14}C gamma emitters; gross beta activity and gross alpha activity	Bq/m^3
2	Suspended particles	Six in the Galilaukė site:	Once a quarter	Gamma spectroscopic analysis of samples: LAND 36-2000 IEC	Specific activity of 14C	Bq/kg of dry

		two land reclamation ditches, the Drūkšta river and lake Drūkšiai. **Two in the Stabatiškė site: one in water bodies located in the territory of the site and one in the land reclamation canal.**		1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis	gamma and alpha emitters (once a year)	matter
3	Bottom deposits	Three in the Galilaukė site: two land reclamation ditches, lake Drūkšiai. **Two in the Stabatiškė site: one in a water body located in the territory of the site and one in the land reclamation canal.**	Once a year	Gamma spectroscopic analysis of samples: LAND 36-2000 IEC 1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis	Specific activity of gamma and alpha emitters	Bq/kg of dry matter
4	Aquatic plants	Two in the Galilaukė site: land reclamation ditches in the Galilaukė site. **Two in the Stabatiškė site: three in water bodies located in the territory of the site.**	Once a quarter during the warm season	Gamma spectroscopic analysis of samples: LAND 36-2000 IEC 1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis Specific activity of ^{14}C using liquid scintillation counting method	Specific activity of 14C gamma and alpha emitters (once a year)	Bq/kg of dry matter
5	Fish	Two in the Galilaukė site: lake Drūkšiai and the Drūkša river. **One in the Stabatiškė site: one in water bodies located in the territory of the site.**	Once a year	Gamma spectroscopic analysis of samples: LAND 36-2000, IEC 1452:1995 Radiochemical evolution of Pu isotopes and alpha spectroscopic analysis	Specific activity of gamma emitters	Bq/kg of wet matter



Stabatiškės aikštelės riba	Boundary of the Stabatiškė site
Orientacinė kapinyno vieta	Reference location of the repository
Ėminių ėmimo vietos:	Locations of sampling of:
Vandens	Water
Dugno nuosėdų	Bottom deposits
Vandens augalų	Aquatic plants
Žuvų	Fish

Fig. 6.5 Layout of monitoring points of aquatic ecosystem in the vicinity of the repository in the Stabatiškė site



Vosyliškių gūbrys	Vosyliškės ridge
Varniškių gūbrys	Varniškės ridge
Švikščionių gūbrys	Švikščionys ridge
Orientacinė kapinyno vieta	Reference location of the repository
Ėminių ėmimo vietos:	Locations of sampling of:
vandens	water
dugno nuosėdų	bottom deposits
vandens augalų	aquatic plants
žuvų	fish
Absoliutinis aukštis, m	Absolute height, m
Melioracijos kanalai	Land reclamation canals
Galilaukės aikštelė	Galilaukė site
Šlapynės	Wetlands
K 12 baseinas	Basin K 12
K 2 baseinas iki kelio Vosyliškės-Močionys	Basin K 2 up to the Vosyliškės-Močionys road
K 8 baseinas	Basin K 8

Fig. 6.6 Layout of monitoring points of aquatic ecosystem in the vicinity of the repository in the Galilaukė site

6.5. Quality assurance

Quality of data must be assured in compliance with the quality assurance programme (developed according to the provisions of standard LST ISO 17025) of the laboratory that performs monitoring. Devices and systems must be protected, installed, maintained and calibrated so as to minimise their exposure to hazardous environmental factors. Verification of devices must be carried out according to the established procedure. To assure the quality of data, the monitoring system must be installed, tested, calibrated, operated and updated in line with the standards applicable in the nuclear industry *(Quality*

Assurance ..., 1996), by implementing the quality assurance programme.

6.6. Dose assessment

Mathematical models of radionuclide dispersion shall be used for the assessment of doses. The applied models must cover the most important part of the biosphere. The assessment of the dose of members of a critical group must consider all significant radionuclides using various means to escape into the environment from a source of pollution. The internal committed dose, which is caused by radionuclides inhaled or entering the digestive system through the year, and the external dose, which results by radionuclides present in the air and on the surface of the earth, are added up.

The assessment of doses is gradual: first of all, the simplest and most conservative model is applied, which does not consider radionuclide dispersion in the environment; if the obtained results do not satisfy, general models shall be applied and reference shall be made to generally approved indicators of radionuclide dispersion, the lifestyle and nutrition of people. The most accurate results are obtained by applying models characteristic to the locality considering the actual radionuclide dispersion and exposure routes and the lifestyle and nutrition of people of an actual critical groups, also referring to the actual indicators of radionuclide dispersion in the atmosphere, hydrosphere and lithosphere characteristic to the locality. Models, the key indicators, their values and methods of estimation are provided in references.

6.7. Data recording; reporting and presentation of data

The following data shall be recorded and stored:

- General information about activities (disposed radioactive waste, accumulated radioactive waste);
- Results of all measurements provided by the monitoring programme;
- Activity of radionuclides released into water (by month);
- Comparison of the activity of radionuclides released into the environment with the threshold activity; the value of the rationed pollution;
- Assessed doses of members of critical groups caused by radionuclides released through the year;
- Unplanned release of radionuclides into the environment, and other important information.

The monitoring report shall consist of the following:

- General information about activities (disposed radioactive waste, accumulated radioactive waste);
- Results of all measurements provided by the monitoring programme;
- Activity of radionuclides released into water (by month);
- Comparison of the activity of radionuclides released into the environment with the threshold activity; the value of the rationed pollution;
- Trends of pollution and pollution change, analysis thereof;
- Assessed doses of members of critical groups caused by radionuclides released through the year;
- Analysis of the unplanned release of radionuclides into the environment, and other important information.

The annual radiological monitoring report shall be submitted to the Ministry of

Environment, the Radiation Protection Centre of the Ministry of Health, the VATESI and the municipality in which the repository is located by April 1 of the next calendar year.

7. EMERGENCY SITUATIONS

This chapter presents the results of the environmental impact assessment under emergency situations: potential emergency situations and accidents that may cause significant radioactive effluents and carry-overs are discussed. Possible outcome and its environmental impact is preliminary assessed and discussed. The assessment is based on the analysis of exposure, caused operational deviations, emergency situations or accidents occurring while handling grouted packages of spent ion-exchange resins, perlite and sediments of evaporated concentrate. This analysis is based on the existing information, which is rather limited. A more thorough assessment of emergency situations will be repeatedly performed during the design of the repository and while assessing its safety. Information about waste of all types to be disposed in this repository and about characteristic features of technological installations will then be analysed.

The design, construction and operation of the near-surface repository must minimise the probability of emergency situations having significant environmental impact from the radiation protection viewpoint. This notwithstanding, the possibility of operational deviations, occurrence of emergency situations or accidents cannot be fully rejected. Therefore, with due consideration to technical solutions of the repository that are actually being implemented, a thorough safety analysis of the repository will be performed during the design and construction of the near-surface repository, also actual measures to reduce the impact of emergency situations will be provided, plans for the prevention and liquidation of potential radiological emergency will be developed and the staff will be trained accordingly.

In case of an emergency situation (once the increased pollution is detected in separate objects of the repository, an accident occurs during the transportation of a package, etc.), the radiation situation will be assessed, the source of pollution will be identified, the outcome of the accident affecting the staff and the environment will be determined, as well as the required radiation protection measures and other specific features of the emerging situation will be established. Accident localisation measures and counter-measures provided for in advance or, if necessary, additionally developed will be implemented. The analysis of causes of the accident will be performed and factors correcting the operation of the repository will be approved that would allow to avoid similar emergency situations during further operation of the repository.

Emergency situations that result in radiation may occur as soon as the transportation of radioactive waste into the near-surface repository and the disposal of the said waste in the said repository starts. Considering factors that cause emergency situations, the development of the near-surface repository may be conditionally divided into two stages, viz. the disposal of waste (operation of the repository) and the surveillance of the repository as well as further development of the repository (Table 1.4.1).

Emergency situations that are likely to occur during the waste disposal stage (that will last for approximately 20 years) are related to the transportation of radioactive waste to and within the repository, interim storage, transfer and final disposal of radioactive waste packages, operation and maintenance of equipment and installations used in the near-surface repository. Forecasted external phenomena (e.g., natural phenomena) will not cause any significant emergency situations during this development stage of the repository, if design and construction works have been carried out properly and if operation and maintenance is properly performed.

After the operation of the repository is completed, the transportation, storage, transfer and disposal of radioactive waste will no longer be performed. Equipment that are no longer required will be dismantled. The repository will be covered with a cap, and an institutional surveillance of the repository will be carried out for approximately 300 years.

7.1. Emergency situations during radioactive waste disposal

7.1.1. Delivery of radioactive waste packages not eligible for disposal to the repository

The near-surface repository will not have any radioactive waste treatment facilities. All radioactive waste packages to be disposed in the near-surface repository must be conditioned before their delivery to the repository. The manufacturer of waste packages must guarantee the quality of these packages, while the organisation that operates the repository must verify their compliance with the eligibility criteria (*Bendrieji radioaktyviųjų ..., 2003*). Only then the package may be delivered to the near-surface repository for disposal. Radioactive waste packages will be additionally in the near-surface repository in order to verify their eligibility according to the recommendations of the IAEA (*Inspection and ... 2000; Tsyplenkov V., ... 2006*).

However, there is a possibility that the radioactive waste package will be damaged during the transportation to the repository. Damage may occur as a result of e.g. an accident during the transportation (Chapter 7.1.3). The damaged radioactive waste package will remain in the transportation cask and will be delivered to the radioactive waste packages reception area.

Radioactive waste packages will be received and inspected in the packages reception area and the packages control and inspection area of the interim storage facility. All operations of transfer of the package between the areas will be performed and controlled remotely; therefore, the staff will not be subject to any additional exposure during the handling of radioactive waste packages not meeting the eligibility criteria. The interim storage building will be designed with due consideration to potential emergency situations. The thickness of walls will be such that radiation fields outside the building (while handling and storing ineligible radioactive waste packages) would be acceptable as far as radiation protection is concerned. The building will have a ventilation system equipped with filters preventing radioactive aerosols from escaping into the environment. If the handling of packages (decontamination or liquidation of accident results) results in the formation of radioactive liquids, they will be collected in the special drainage system of the interim storage facility and will not escape into the environment. Neither the staff of the repository nor the residents will be exposed to unanticipated ionising radiation, and no environmental impact will be caused during the handing of ineligible radioactive waste packages or during their storage in the interim storage facility.

Ineligible radioactive waste packages as well as radioactive waste generated during the handling of such packages will be returned to their manufacturer for repeated treatment.

7.1.2. Emergency situations during the transfer of packages

An overhead crane performing the transfer of radioactive waste packages from one zone to another and the handling of packages will be mounted in the interim storage facility. A similar overhead crane performing the transfer of radioactive waste from the vehicle that delivered radioactive waste packages to the vault for disposal will be mounted under the shelter. Both cranes shall be remotely controlled from the central control room. Only radioactive waste packages meeting the eligibility criteria will be handled in the vault area.

7.1.2.1. Suspension of a radioactive waste package

It is possible that during the transfer of a package the transfer will be temporarily interrupted and the radioactive waste package will be suspended in the air. This situation may occur as a result of a power-cut or a breakdown of the crane.

The staff will not be present during the transfer of packages in the areas of the temporary storage facility where the radiation dose rate may increase in case of emergency. The interim storage building will be designed with due consideration to potential emergency situations, including during the transfer of ineligible radioactive waste packages. The thickness of walls will be such that in an emergency the ionising radiation outside the interim storage facility would be tolerable from the point of view of radiation protection. Therefore, the staff of the repository and the residents will not be exposed to unanticipated ionising radiation and no environmental impact will be caused if a package is suspended. There will be enough time to assess the situation and to develop and implement counter-measures.

When a package is transferred in the vault area, the staff (e.g. the driver of the vehicle) will be in a special area safe from the point of view of radiation protection. Therefore, if a radioactive waste package is suspended, the staff of the vault area shall not be subject to any unanticipated exposure. In case of an emergency, the dose rate of ionising radiation will increase in the repository area and outside this area. If a package containing grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate with the highest activity is suspended, the resulting dose rate will change from approximately 0.55 mSv/h at a distance of 1 m to 2.2×10^{-5} mSv/h at a distance of 150 m outside the fence of the repository (see Fig. 4.3.1.2. Dependence of an equivalent dose rate on the distance from the unshielded cask). Assuming that the emergency is liquidated within 24 hours, the maximum exposure of a resident would be the effective dose of approximately 5.3×10^{-4} mSv. The exposure dose of a resident shall not exceed the dose constraint of 0.2 mSv (*Normatyvinis dokumentas ..., 2001*). If for any reason the emergency cannot be liquidated within 24 hours, provisional measures shielding the package and reducing the dose rate of ionising radiation may be applied. In order to avoid any causeless exposure of the staff, and subject to the radiation situation, the movement of the staff involved in the liquidation of the emergency and other activities in the repository may be restricted. If a radioactive waste package is suspended and urgent measures are applied to localise the emergency, if necessary, the environmental impact will be insignificant and will not exceed the threshold level.

7.1.2.2. Falling down of a radioactive waste package

There is a very small possibility that a radioactive waste package will fall down. Technical and organisational measures should ensure that the probability of such event is sufficiently low (e.g. 5×10^{-4} per year) and that such accident does not occur during the whole operation of the repository. However, the environmental impact assessment does assess the possible effects of a falling down of a radioactive waste package.

If a radioactive waste package falls down, it may become damaged. During the impact, radioactive aerosols may be generated and released, which would spread in the air. The amount of aerosol is generated *pro rata* to the impact energy. Therefore, the possibly largest fraction of radioactive aerosols may be generated and released into the environment during the falling down of the package from the maximum height of lifting. The package that fell down, being the object of ionising radiation, will also cause the increase of the dose rate of ionising radiation. Its rate will depend upon the nature of the damage of the package. Once the package or any part thereof disintegrates, radioactive dust may be generated, which will cause the surface pollution of surrounding objects. No radioactive liquids will be formed, as only solid or solidified radioactive materials are disposed in the repository.

A radioactive waste package may be dropped either in the interim storage facility or in the vault area. In the vault area, the maximum dropping height of the package would be approximately 7 m. If packages are loaded in the same height in the interim storage facility as in the vault, the highest dropping height would be similar. If the structure of the interim storage facility provides for a lower storage height of packages, which is more convenient from the point of view of operation, the maximum dropping height of the package would be lower.

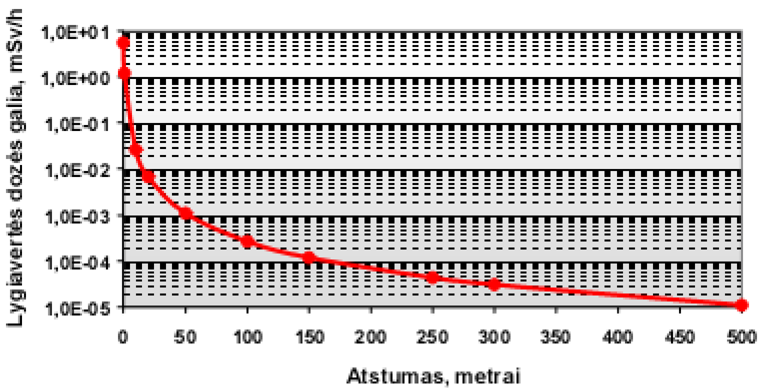
If a package falls down in the interim storage facility, no environmental impact will be caused. The staff will not be present during the transfer of packages in the areas of the temporary storage facility where the exposure rate may increase in case of emergency. The interim storage building will be designed with due consideration to potential emergency situations, including during the transfer of ineligible radioactive waste packages. The thickness of walls will be such that in an emergency the ionising radiation outside the interim storage facility would be tolerable from the point of view of radiation protection. The building will have a ventilation system equipped with filters restricting radioactive aerosols from escaping into the environment in case of an emergency. If the liquidation of accident results causes the formation of radioactive liquids, they will be collected in the special drainage system of the interim storage facility and will not escape into the environment. Therefore, the staff of the repository and the residents will not be exposed to unanticipated ionising radiation in the interim storage facility and no environmental impact will be caused if a package falls down. There will be enough time to assess the situation and to develop and implement counter-measures.

The most significant environmental impact can be caused if a radioactive waste package falls down from the highest lifting height near the vault of the repository. In this case the amount of radioactive aerosols that may be potentially released would be the largest, while the direct ionising radiation caused by the falling package is less shielded than if the package would fall inside the vault.

Environmental impact resulting from the release of aerosols caused by the falling down of a package of grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate has been analysed in the environmental impact assessment report on the installation of a grouting facility for solidifying liquid radioactive waste and on the construction of an interim storage facility at the Ignalina NPP (*Cementavimo įrenginio ..., 2002*). For the assessment of a potential release of aerosols it was assumed that a cask turns over in the height of 4.5 m and drums containing solidified radioactive waste fall down. Once metal drums fall down, they crack, and radioactive waste is exposed. The cask itself falls on one of the drums and breaks it down completely. It was assumed that the generation of radioactive aerosols is caused by the whole impact energy, conservatively rejecting the possibility that some of this energy would be consumed for the deformation of structures, the cask and the floor. Under such assumptions, the fraction of aerosols released from the dropped cask would amount to 1.2×10^{-4} of the mass of radioactive materials. It was also assumed that this cask contained grouted waste with the highest activity, which results in the highest activity of aerosols. Such aerosols are directly released into the environment, and they spread in the environment under unfavourable meteorological conditions. The population exposure within the radius of 200-3000 m around the place where the cask fell has been calculated. External and internal (through respiratory and digestive tract) population exposure paths have been assessed. It was assumed that a resident spent 2000 hours in the considered area per year (i.e., the locality was granted the status of a sanitary zone), and that the intake of food was terminated 24 hours following the accident. The calculation results show that residents are subject to the maximum exposure during the firs year of the accident; however, beyond 200 m the annual effective dose does not exceed 5.6×10^{-5} mSv. The dose accumulated by a resident over the period of 50 years would amount to 5.6×10^{-4} mSv.

If a package falls down in a near-surface repository, the maximum dropping height would be higher. On the other hand, conditioned radioactive waste packages are delivered to the repository. The contents of the cask, e.g. drums and gaps among them, will be grouted into a solid monolith block. In this case no drums will drop out of the cask, while the cask body will serve as an additional barrier protecting the drums from breaking down and the release of aerosols.

It is conservatively assumed, that if a cask containing grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate falls down from the height of 7 m, it breaks down at the impact, metal drums crack and radioactive waste is exposed, and the fraction of released aerosols is approximately 1.0×10^{-4} of the mass of radioactive materials. Making a similar assessment of population exposure (*Cementavimo įrenginio ..., 2002*), the annual effective dose behind the future fence of the near-surface repository will not exceed 1.0×10^{-4} mSv. The exposure dose of a resident shall not exceed the dose constraint of 0.2 mSv (*Normatyvinis dokumentas ..., ,2001*). The analysis of the results of the suspension of a radioactive waste package shows that the suspended package of grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate cause the effective dose of up to 5.3×10^{-4} mSv per day. This exposure is more than five times the annual dose caused by released aerosols. Therefore, in the case of the falling down of such package, urgent measures should be taken to limit the direct exposure caused by ionising radiation. Making the most conservative assumption and assuming that the package breaks down completely, the resulting dose rate will change from approximately 1.2 mSv/h at a distance of 1 m to 1.2 $\times10^{-4}$ mSv/h at a distance of 150 m outside the fence of the repository (Fig. 7.1.2.1). Assuming that the direct exposure caused by ionising radiation is limited within 24 hours, the exposure of a resident at a distance of at least 150 m would be the effective dose of approximately 3×10^{-3} mSv. The exposure dose of a resident shall not exceed the dose constraint of 0.2 mSv (*Normatyvinis dokumentas ..., 2001*). If a radioactive waste package falls down and urgent measures are applied to localise the emergency the environmental impact will be insignificant and will not exceed the threshold level.



Lygiavertės dozės galia, mSv/h	Equivalent dose rate, mSv/h
Atstumas, metrai	Distance, m

Fig. 7.1.2.1. Dependence of an equivalent dose rate on the distance from the broken package

7.1.3. Accidents during the transportation of radioactive waste packages to the repository and inside the repository area

The following accidents may occur during the transportation of radioactive waste packages to the repository or inside the repository area: the vehicle breaks down and stops; the vehicle goes off the road (it may turn over or take fire); the vehicle collides with an obstacle, e.g. with another vehicle (the collision may cause the vehicle to go off the road, to turn over, to take fire, especially if it collides with another vehicle transporting flammable materials); fire of a vehicle.

During the transportation, including in the case of an accident during the transportation, the radiation protection will be ensured by the conformity of radioactive waste packages and the transportation cask with regulations for the safe transportation of radioactive waste (*Regulations for the Safe ..., 2004*), also additional organisational and technical measures.

Regulations for the safe transportation (*Regulations for the Safe ..., 2004*) define technical requirements for the package (structure, tests, etc.) depending upon the activity and other characteristics of transported radioactive material, in order to ensure the radiation protection of the staff and population under normal operation conditions as well as in case of emergency during the transportation of radioactive materials by public roads. According to the initial assessment, radioactive waste disposed in the near-surface repository may be classified as materials of group LSA III; the package used for the transportation of such materials must conform to the requirements applicable to packages of class IP-II or IP-III.

Radioactive pollution during transportation or increased exposure during emergency is possible only of the transportation cask is damaged. In any other case radioactive materials will not be released into the environment and the dose rate of ionising radiation will not increase. Therefore, if the vehicle breaks down, turns over, takes fire, etc., and the cask for the transportation of a radioactive waste package remains intact, the dose rate of ionising radiation may locally increase, just as under normal transportation conditions. Once the radioactive waste package is removed, ionising radiation will be reduced to the natural (background) level. During the liquidation of accident results, the presence of residents near the site of the accident may be temporarily restricted, thus avoiding any unanticipated exposure of population. The transportation cask is designed with due consideration to regulations for the safe transportation and potential characteristics of an accident; therefore, it will ensure the radiation protection in case of other possible emergencies. The sufficiency of safety measures will be justified by the safety analysis report. The fire of the vehicle is additionally discussed in Chapter 7.1.4.

Additional organisational and technical measures will be used to minimise the probability of any accidents and, if an accident does occur, to immediately localise and liquidate the accident results. The speed restriction of the vehicle, the timely maintenance of the transportation road, the prohibition to transport packages under bad road conditions (glazed frost) or weather conditions (heavy fog, pouring rain, snowstorm) are measures that help reduce the possibility of accidents. Under bad weather conditions it is more difficult to perform accident localisation and liquidation works. As the distance between the manufacturer of radioactive waste packages (Ignalina NPP) and the near-surface repository is small, the response time of services that localise and liquidate the accident (fire fighting brigades, technical assistance teams, etc.) will be short. With the existing development level of modern telecommunications, a continuous monitoring of movement of the vehicle transporting radioactive packages can be easily ensured.

When the package is transported in the controlled area of the repository, it must be subject to respective safety regulations (*Regulations for the Safe ..., 2004*).

7.1.4. Fire in the controlled area of the repository

Fire in the near-surface repository that may have radiation results is possible only in facilities where radioactive materials are either kept or stored. Such facilities include the interim storage facility of the repository, the vehicle transporting radioactive waste packages, and vaults, either filled or being filled up. Other facilities of the near-surface repository may also have small secondary amounts of radioactive waste. However, due to the low activity and small amount of these materials, the impact in the case of fire would be only local, and no significant environmental impact would be caused.

Only conditioned radioactive waste packages will be handled (stored, transported, disposed) in the near-surface repository. The conditioning will assure (*Bendrieji radioaktyviųjų ..., 2003*) the incombustibility of radioactive waste packages. Packages will not contain any pyrophoric substances or substances with the ignition temperature of lower than 60°C. There will be no chemical substances or items that may cause explosion. Radioactive waste packages must survive external fire and meet the established regulations for safe transportation (*Regulations for the Safe ..., 2004*). Measures will be applied to packages in order to prevent the accumulation of flammable and explosive gas.

The potential fire load in the handling area of radioactive waste packages will be minimal. In the vault area and in the interim storage facility the potentially flammable materials will include cables for the crane power supply, illumination and communication system, as well as crane lubricants. As far as vehicles are concerned, the potentially flammable materials will include automobile fuel and lubricants. During the detail design process the potential fire load will be minimised, and appropriate fire alarm and fire fighting measures will be selected. Organisational measures will minimise the fire threat.

Inflammable radioactive materials, the potentially low fire load, and appropriate fire alarm and fire fighting measures will ensure a low possibility of a fire in the controlled area of the repository. Fire, if any, would be local and would be promptly extinguished without causing any significant release of radioactive materials into the environment. Such fire in the repository will have no impact on the environment. Emergency prevention and liquidation plans will be co-ordinated with the Fire and Rescue Services for the protection of Visaginas and the Ignalina Nuclear Power Plant.

7.2. Emergency situations during the repository surveillance and subsequent development stages

Radiation consequences of the following emergency situations shall be analysed: the flooding of the repository during heavy rainfall or flood, a rapid degradation of engineering barriers, and an inadvertent intrusion into the vaults of the near-surface repository.

7.2.1. Flooding of the repository during heavy rainfall or flood

The selection of the repository site and the structure of the repository will prevent waste stored in the repository from being flooded during heavy rainfall or flood, if the repository is normally operated and the performance of engineering barriers are as designed. The safety of the repository is based on the condition that vaults of the repository are constructed above the highest possible groundwater rise level. The surface conditions of the repository site will ensure a sufficient and stable (in the long range) run-off of the potential maximum precipitation amount, and thus prevent the site from flooding.

Section “Notes on the probability of flooding the territory” in Chapter 4.1.1 “Water” of this Report demonstrates that in the Galilaukė, Apvardai and Stabatiškė sites the risen surface water will not reach the bottom of the planned repository even during the potentially heaviest flood.

Sections “Engineering geological conditions” and “Valuable characteristics of the underground and their suitability for the planned economic activity” in Chapter 4.1.5 “Underground” of this Report shows that all three sites are characterised by sufficiently good surface flow conditions and long-term stability of hills.

Local micro-unevenness of hill slopes may be rectified during the construction of the repository.

During the operation of the near-surface repository (during the disposal of radioactive waste), the drainage system designed with due consideration to potential emergency conditions will be constructed in the repository site (*Reference Design ..., 2002, Rimidis A. 2005*). After the closure of the repository, with due consideration to the specific character of the sites and the best international practice (*Technical Considerations..., 2001*), the vaults of the repository will be covered by a long-lived erosion resistant cap, which will ensure sufficient surface flow conditions. RATA will perform the post-closure surveillance of the repository. Afterwards, the state supervision and control will be performed.

7.2.2. Rapid degradation of engineering barriers

During the active surveillance of the repository (100 years after the closure of the repository) the physical protection of the repository will be secured, maintenance works will be performed, the monitoring of the repository and its surroundings will be carried out, and corrective measures will be taken, if required (*Mažo ir vidutinio ..., 2002, Surveillance and ..., 2004*). At the start of the post-closure evolution, if construction and closure works are properly performed, the possibility of an unanticipated degradation of engineering barriers is very low; if it occurs, it will be noticed in time, and the required corrective actions will be taken. No environmental impact significant from the radiation point of view is expected to occur during this initial period of the surveillance of the repository.

During the period of passive surveillance of the repository (200 years after the period of active surveillance) the use of land in the territory of the repository shall be restricted. For this purpose the required documents are kept and certain types of activities are banned in the area of the repository. No corrective actions shall be planned for this period. The established ban on certain types of activities in the area of the repository must be sufficient and the enforcement of the ban must be controlled so as to prevent any unanticipated degradation of engineering barriers. During the passive surveillance of the repository the expected degradation of engineering barriers will be assessed by the scenario of the degradation of engineering barriers. The scenario assumes that the degradation of engineering substances located under the cap of the repository starts at the beginning of the passive surveillance of the repository, and at the end of the said period the engineering barriers are changed and they no longer restrict the water flow across the repository. Possible engineering barriers formed from short-termed water-insulating materials (such as polymeric films, bitumen, etc.) have not been considered at all. However, restrictions of activities in the territory of the repository effective are sufficient enough to preserve the integrity and the design characteristics of the cap of the repository. Chapter 4.3.2 “Water” of this Report describes this scenario in more detail, presents the calculation results and assesses the environmental impact.

When the surveillance of the repository ends, economic activity or land utilisation at the site of the repository will no longer be prohibited or otherwise restricted (*Mažo ir vidutinio ..., 2002*). Therefore, the scenario of long-term degradation of engineering barriers of the repository conservatively assumed that 300 years after the closure of the repository all engineering barriers will degrade so that they will no longer restrict the water flow across the repository. Chapter 4.3.2 “Water” of this Report describes this scenario in more detail, presents the calculation results and assesses the environmental impact. Chapter 7.2.3 analyses the consequences of the destruction of engineering barriers resulting from inadvertent intrusion.

7.2.3. Inadvertent intrusion into the vaults of the repository

Inadvertent intrusion into the vaults of near-surface repository is possible when economic activity or land utilisation at the site of the repository will no longer be prohibited or otherwise restricted upon the expiration of the repository surveillance period (*Mažo ir vidutinio ..., 2002*). The possibility that some of the engineering barriers of the repository may be destroyed or otherwise damaged as a result of any economic activities must be considered.

Inadvertent intrusion into the near-surface repository is possible by destroying surface engineering barriers of the repository, such as the cap of the repository, the structure of the vaults, or damaging packages and exposing the disposed waste. If the activity of waste is significant at the time of the intrusion, the intruders may be subject to both external and internal exposure exceeding the applicable radiation protection requirements. Therefore, the activity of radioactive waste to be disposed of must be limited with due consideration to the consequences of inadvertent intrusion into the vaults of the repository.

The activity of radioactive waste packages disposed in the near-surface repository may be described by numbers X and Y (Chapter 2.1). Number X evaluates the hazard of disposed radioactive materials in the case of an inadvertent intrusion into the repository. Where number X calculated for a radioactive waste package does not exceed 1, such package shall be considered to be eligible for disposal in the near-surface repository. In the case of an inadvertent intrusion into the repository, the intruder's exposure shall not exceed the applicable radiation protection requirements (*Bendrieji radioaktyviųjų ..., 2003*).

Threshold specific activity values applicable to a radioactive waste package must be known in order to calculate number X. These threshold specific activity values depend upon the technology of conditioning of the waste to be disposed of, structural characteristics of surface engineering barriers, as well as the time and manner of the intrusion into the vaults of the repository. In case of an inadvertent intrusion, the established threshold specific activity values relatively do not depend upon the characteristics of the selected site of the repository.

RATA document (*Mažo ir vidutinio ..., 2003*) presents the preliminary values of threshold specific activity for grouted short-lived low and intermediate level radioactive waste packages expected to be disposed of in the near-surface repository. The preliminary values of threshold specific activity have been established with due consideration to the provisions of the normative document (*Mažo ir vidutinio ..., 2002*) and to the conceptual design of the near-surface repository (*Reference Design ..., 2002*). Considering the low probability of an inadvertent intrusion, the annual permissible dose of exposure of a member of the critical group of 5 mSv has been selected as the parameter of the radiation protection (*Higienos norma HN 73:2001, 2002*).

The considered scenario of an inadvertent intrusion assumed that the intrusion occurs after the termination of the post-closure surveillance. For the purpose of calculations it was assumed that the time of intrusion is relatively short in comparison with the half-lives of degradation; therefore, the reduction of the activity during exposure shall not be considered. It is assumed that during the intrusion some vaults of the repository are damaged, surface engineering barriers are completely destroyed and all radioactive waste disposed in the vaults are exposed.

For the purpose of the calculation of ionising radiation exposure it was assumed that the activity of exposed material is equally distributed in a certain volume of the top layer of the soil. The sum of the following factors influences the dose of a member of the critical group: accidental swallowing of contaminated earth, inhalation of contaminated dust and direct exposure resulting from contaminated soil. Dose multipliers pertaining to swallowed and inhaled radionuclides are obtained from a document (*Higienos norma HN 73:2001, 2002*).

For the purpose of the assessment of the dilution of radioactive waste it was assumed that the material determining the exposure consists of the exposed radioactive waste, which is evenly mixed with material surrounding radioactive waste in the vault of the near-surface repository. Surface barriers of the repository and materials present among the vaults of the repository shall be exposed without mixing them with the contents of the vault of the repository. These materials are either removed prior to the intrusion into the vault containing radioactive waste or covered with excavations from deeper layers; therefore, they do not dilute radioactive waste. Such position first of all determines a more conservative assessment of the exposure; therefore, lower threshold activity values are obtained. Second of all, the obtained results do not depend upon external engineering barriers covering the vault of the repository.

The calculation of number X relating to a package containing grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate is presented in Table 7.2.1. The legend of each column is additionally explained in the notes to Table 7.2.1.

Table 7.2.1. The calculation of number X relating to a package containing grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate

Radionuklidas	**$C_{i,max}$*, Bq/m^3 (1)**	**$C_{i,max}$, Bq/m^3 (2)**	**C_i, Bq/m^3 (3)**	**C_i / $C_{i,max}$**
H-3	$4{,}0\times10^{21}$	$4{,}2\times10^{21}$	$4{,}5\times10^{7}$	$1{,}1\times10^{-14}$
C-14	$5{,}0\times10^{12}$	$5{,}2\times10^{12}$	$2{,}1\times10^{9}$	$4{,}1\times10^{-4}$
Cl-36	$3{,}0\times10^{12}$	$3{,}1\times10^{12}$		
Ni-59	$5{,}0\times10^{13}$	$5{,}2\times10^{13}$	$1{,}5\times10^{7}$	$2{,}9\times10^{-7}$
Ni-63	$1{,}0\times10^{14}$	$1{,}0\times10^{14}$	$1{,}8\times10^{9}$	$1{,}8\times10^{-5}$
Sr-90	$6{,}0\times10^{13}$	$6{,}3\times10^{13}$	$5{,}7\times10^{6}$	$9{,}2\times10^{-8}$
Nb-94	$4{,}0\times10^{8}$	$4{,}2\times10^{8}$	$2{,}4\times10^{8}$	$5{,}9\times10^{-1}$
Tc-99	$5{,}0\times10^{12}$	$5{,}2\times10^{12}$	$2{,}0\times10^{4}$	$3{,}8\times10^{-9}$
I-129	$3{,}0\times10^{10}$	$3{,}1\times10^{10}$	$1{,}7\times10^{3}$	$5{,}5\times10^{-8}$
Cs-137	$1{,}0\times10^{12}$	$1{,}0\times10^{12}$	$6{,}4\times10^{9}$	$6{,}1\times10^{-3}$
Ra-226	$8{,}0\times10^{8}$	$8{,}3\times10^{8}$		
U-234	$1{,}0\times10^{10}$	$1{,}0\times10^{10}$	$3{,}2\times10^{1}$	$3{,}1\times10^{-9}$
U-235	$4{,}0\times10^{9}$	$4{,}2\times10^{9}$	$7{,}6\times10^{-1}$	$1{,}8\times10^{-10}$
U-238	$8{,}0\times10^{9}$	$8{,}3\times10^{9}$	$9{,}5\times10^{0}$	$1{,}1\times10^{-9}$
Np-237	$1{,}0\times10^{9}$	$1{,}0\times10^{9}$	$1{,}3\times10^{0}$	$1{,}2\times10^{-9}$
Pu-238	$1{,}0\times10^{10}$	$1{,}0\times10^{10}$	$5{,}9\times10^{3}$	$5{,}7\times10^{-7}$
Pu-239	$8{,}0\times10^{8}$	$8{,}3\times10^{8}$	$1{,}0\times10^{4}$	$1{,}2\times10^{-5}$
Pu-240	$9{,}0\times10^{8}$	$9{,}4\times10^{8}$	$5{,}7\times10^{3}$	$6{,}0\times10^{-6}$
Pu-241	$4{,}0\times10^{11}$	$4{,}2\times10^{11}$	$1{,}5\times10^{6}$	$3{,}5\times10^{-6}$
Am-241	$1{,}0\times10^{9}$	$1{,}0\times10^{9}$	$2{,}2\times10^{4}$	$2{,}1\times10^{-5}$
Suma, skaičius X (4)				0,59

Radionuklidas	Radionuclide
Suma, skaičius X (4)	Total amount, number X (4)

Where:

(1) $C_{i,max}$* – threshold specific activity values of a grouted radioactive waste package (*Mažo ir vidutinio ..., 2003*);

(2) $C_{i,max}$ – threshold specific activity values recalculated for a package of grouted spent ion-exchange resins, filtration substance (perlite) and sediments of evaporated concentrate;

(3) C_i – concentration of an isolated radionuclide in a package of grouted spent ion-exchange resins, filtration substance (perlite) and sediments of evaporated concentrate. C_i has been calculated based on the maximum activity of radioactive waste and not considering any possible interim storage of the package prior to its disposal in the near-surface repository.

(4) Number X shall be calculated as follows (*Bendrieji radioaktyviųjų ..., 2003*):

$$X = \sum C_i / C_{i,\max} .$$

The preliminary values of threshold specific activity $C_{i,max}$* presented in the RATA document (*Mažo ir vidutinio ..., 2003*) have been calculated for the disposal cask provided in the conceptual design of the near-surface repository (*Reference Design..., 2002*). The volume of this cask is 4.61 m^3; 432 such casks are disposed in a single vault of the repository. For the purpose of another disposal cask the values of threshold specific activity must be recalculated with due consideration to the changed volume of the waste package and the number of packages in the vault of the repository. For the purpose of a package of grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate, threshold specific activity values $C_{i,max}$ are recalculated assuming that the volume of the package is 5.31 m^3, and 360 such packages will be disposed in a single vault of the repository. Table 7.2.1 demonstrates that calculated number X is 0.59, thus smaller than 1. Therefore, in the case of the assessed inadvertent intrusion into the vaults of the near-surface repository filled with packages of grouted spent ion-exchange resins, perlite and sediments of evaporated concentrate the exposure of the intruders shall not exceed the applicable radiation protection requirements.

8. POSSIBLE TRANSBOUNDARY IMPACT

In view of the provisions of the Convention on Environmental Impact Assessment in a Transboundary Context (*Konvencija ..., 1999*), the potential impact of the planned economic activities on neighbouring countries must be taken into consideration. The impact is assessed for two states situated relatively a short distance away from the area of planned economic activities, viz. the Republic of Belarus and the Republic of Latvia. Other neighbouring countries are located several hundred kilometres away from the area of planned economic activities. The planned economic activity will not affect these countries and is therefore not analysed.

One of the most important peculiarities of the geographical location of the region is the fact that it lies near the border, at the junction of three states (Fig. 8.1). The Ignalina NPP, the source of waste to be disposed off, is also situated in the frontier zone, only 5 km away from the state border, on the shore of a transboundary water body (Lake Drūkšiai).

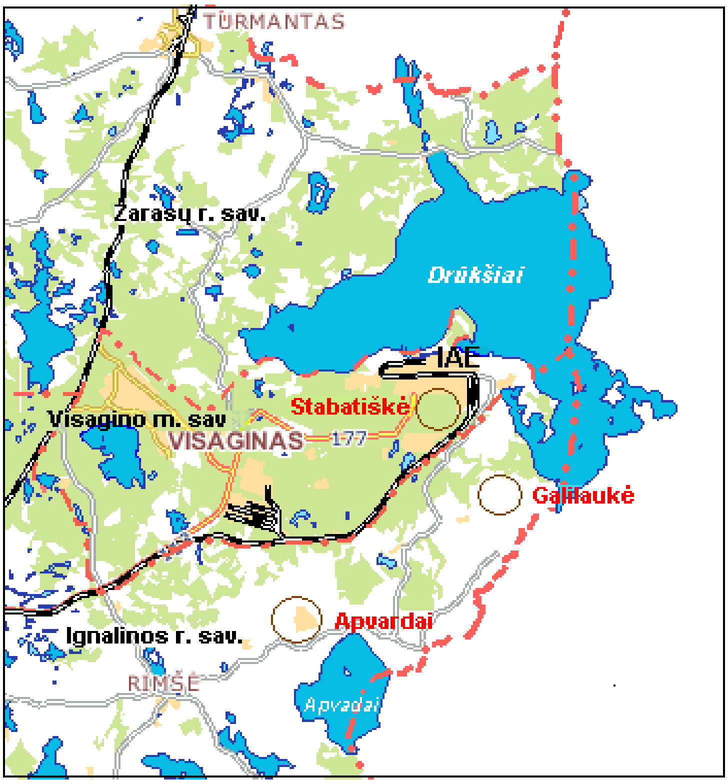


Fig. 8.1 Location of Apvardai, Galilaukė and Stabatiškė sites

A near-surface repository for short-lived low and intermediate level radioactive waste is to be constructed in one of the sites, either Galilaukė, Apvardai or Stabatiškė, as a result of the planned economic activities. All the sites are situated in the eastern part of Lithuania, near its state border with Belarus and Latvia. The Galilaukė site lies some 4 km southeast of the Ignalina NPP. The site is located 0.6 km away from Lake Drūkšiai, 0.7 km west of the Drūkša river and the Lithuanian-Belarus border. The distance between the Galilaukė site and the Lithuanian-Latvian border is approximately 11.5 km. The Apvardai site lies 8 km southwest of the Ignalina NPP and 1.3 km northwest of Lake Apvardai. The border between Lithuania and Belarus runs across the lake. The distance between the Apvardai site and the Lithuanian-Belarus border is 3 km. The distance between the Apvardai site and the Lithuanian-Latvian border is 15.5 km. The Stabatiškė site is at a distance of 4 km from the

Lithuanian-Belarus border. The portion of the border running along Lake Drūkšiai is the closest to the site. 76% (3,700 ha) of this lake belongs to Lithuania, while 24% (1,200 ha) – to Belarus. There are some 11 km to the border with Latvia.

Settlements of the Republic of Belarus

Several major settlements (Drisviaty, Gireishi, Grituny) and some 15 small rural settlements are situated on the Belarusian side at a distance of up to 5 km from the border with Lithuania (Fig. 8.2). The town of Drisviaty, a local centre of services, agricultural production and border protection, has a population of about 300. The settlements of Gireishi and Grituny are situated on either bank of the old river-bed of the Drūkša, some 7 km southeast from Drisviaty. Grituny lies further north and has a population of less than 100. The settlement of Gireishi further to the south used to be the centre of a state farm (sovkhoz), and it grew at that time. Even apartment houses were built then. Gireishi has a population of approximately 250. Barkovshchizna settlement is situated closest to the planned facility (near the Galilaukė site). The Lithuanian side in the area between Lakes Apvardai and Drūkšiai is not connected by roads with the abovementioned settlements. The total population of the 5-km-wide borderland on the Belarusian side is 600-800. The town of Vidzy (with a population of some 2,200) and Braslav (the regional centre with a relatively stable population of ca. 9,500) are local and regional centres in the area.

There are no major settlements in the Latvian frontier zone.

Protected areas

The distance from the planned facility to the Braslav National Park in Belarus established in 1995 is some 20-23 km. The planned repository is over 15 km away from the nearest protected territories in Latvia, the Silene Nature Park and Ilgai and Glushonka Nature Reserves.

The area of the sites has not been included into Lithuania's Eco Net. Only Lake Drūkšiai in their vicinity as an entity of national importance is a part of the abovementioned net. In accordance with the preliminary *Natura 2000* network of the EU's protected nature areas, Lake Drūkšiai and the Drūkša riverside bordering in the **southeast with the sites under consideration** were singled out as habitats of protected bird species (the little crake, spotted crake, sea eagle, marsh harrier, great bittern).

Hydrographical and hydrogeological conditions

The sites under consideration are situated south of Lake Drūkšiai, within its basin.

Lake Drūkšiai belongs to the Daugava basin (Lake Drūkšiai → the Prorva →the Drūkša (called the Drisviata in Belarus) → the Dysna → the Daugava → the Riga Bay of the Baltic Sea). The Rychanka, Drūkša (Apvardė), Smalva, Gulbinė and Gulbinėlė rivers and another six nameless streams flow into Lake Drūkšiai (Table 4.1.1.1), and the Prorva river flows out of it (Table 4.1.1.2). The natural annual water exchange (transmissivity) in Lake Drūkšiai is approximately 29%.

Prior to 1953 two rivers, the Drūkša and the Prorva, used to flow out of Lake Drūkšiai, and the area of the lake was 466 km². 3.5 km downstream from the end of the lake, the Drūkša joined the Apyvardė flowing out of Lake Apvardai. Downstream from the confluence the river was called the Drūkša or Drisviata; 14 km downstream the Prorva fell into it. The total length of the Drūkša was 48.1 km. After a hydro-electric power plant was constructed downstream from Lake Stavokas in 1953, a sluice was installed for the control of the flow. During the same year the Drūkšta (the Drisvėta, or Drisviata in cadastres) was dammed 50 m downstream from the Apvardė mouth by a 3-metre-high dyke (before the lake was dammed, the Drūkšta was an effluent of the lake). The whole flow of Lake Apvardė was thus directed along Lake Drūkšiai (whose basin grew to 613 km³ as a result) and from it – along the new effluent. The 300 kW hydro-electric power plant was decommissioned in 1982; the hydrographical network, however, was not re-naturalised. The Drūkšta dam is in Belarusian territory. The state of the dam and operation conditions are not known. If the dam is demolished or naturally falls in decay, water from Lake Drūkšiai will once again start flowing in two directions, i.e. along the Prorva and the Drūkšta.

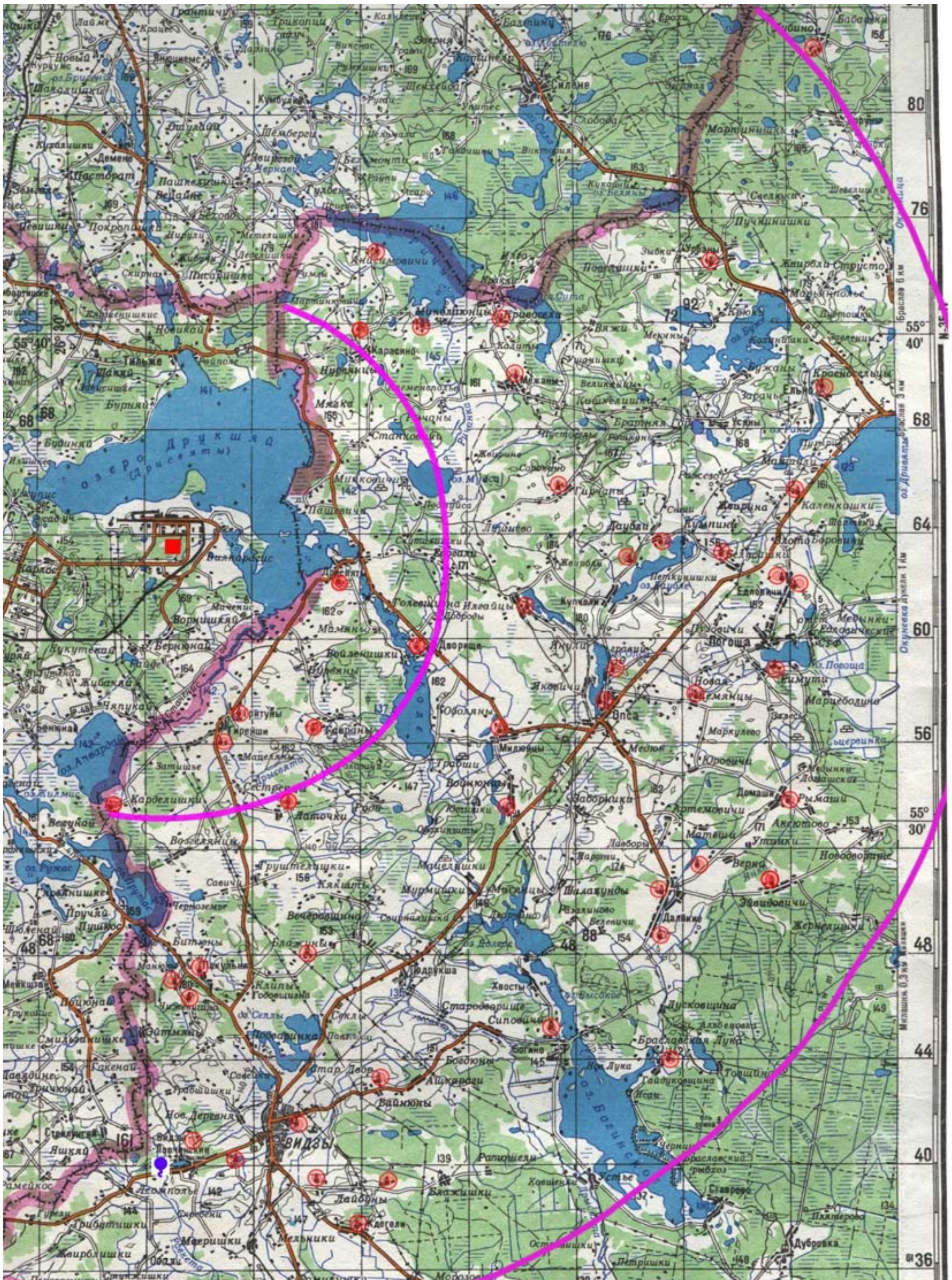


Fig. 8.2 Settlements and water extracting sites in Belarus located within a radius of 10 km and 30 km from the Ignalina NPP.

3. att. Dabas parka "Silene" atrašanās vieta.

Fig. 8.3 Protected areas in Latvia

At present the average flow of the Prorva flowing out from Lake Drūkšiai is 3.2 m³/s. The Prorva's length from the point of outflow to the confluence with the Drūkšta is 12.3 km. Downstream from the confluence with the former Drūkšta the river was bifurcated by man. The Drūkšta is the right-bank tributary of the Dysna. The total hydrographical distance from the outflow point from Lake Drūkšiai to the Dysna is 44.5 km. The total length of the Dysna is 173.4 km, and the area of its basin is 8,179.5 km². Its average flow at Kazėnai is 10 m³/s, and as large as 30 m³/s at Sharkovchizna. Downstream from the confluence with the Drūkšta (Drisviata), the Dysna flows for 113.6 km before falling into the Daugava (near the town of Dysna in Belarus), some 425 km from the mouth of the Daugava. The average flow of the Daugava at the mouth of the Dysna is 288 m³/s, and as large as 451 m³/s at Daugavpils. In its mouth (the Riga Bay), the flow of the Daugava reaches 700 m³/s.

The hydrographical distance from the point of outflow from Lake Drūkšiai to the Riga Bay in the Baltic Sea is about 580 km. Given the location of the candidate sites, it can be stated that the hydrographical distance from Galilaukė, Apvardai and Stabatiškė sites to the Baltic Sea is approximately 587 km, 601 km and 591 km, respectively.

Different kinds of hydraulic installations exist in the environs of the sites that are important in terms of hydrological regime of the area:

1. The sluice in the town of Drisviaty in Belarus on the Prorva channel that regulates the water level in Lake Drūkšiai. The sluice is important both for the operation of the nuclear power plant and for the hydrological regime of the area, as it affects the water level in Lake Drūkšiai and thus (through groundwater) the hydrogeological regime of a part of the basin of the lake.

2. The blind earth dam on the Drisviata river near the former confluence with the Apvarda river. This hydraulic installation changed the flow direction of the natural stream that used to flow out of Lake Drūkšiai, and in interaction with the abovementioned sluice it changed the regime of the water level in Lake Drūkšiai. If the dam disintegrates, the water level in Lake Drūkšiai and the outflow from it can naturally return to the former condition.

On the territory of Belarus within a 10-km radius from the Ignalina NPP fresh groundwater is tapped by artesian wells in a number of small towns and villages, namely, Drisviaty, Dvorishchia, Grituny, Gireishi, Gavrany, Kardelishki (Fig. 8.2). The wells operated in Karasino and Latochki towns are the closest to the Ignalina NPP. Most of the wells are in cattle-breeding farms. The wells tap intermorainic aquifers in Quaternary deposits (Table 8.1). The roof of aquifers lies at depths ranging from 20 to 102 m. The aquifers are 5.5-23 m in thickness and are composed of fine sands, sands of variable grain-size, and gravels. The water level in the wells is 6-12 m from the ground surface. The yield ranges from 0.1 to 0.6 l/s. The aquifers are overlain by 20-100-meter-thick tills and clays.

The quality of water in the used wells, with the exception of the amount of iron, meets the requirements of sanitary standards for drinking water. Anthropogenic pollution has not been observed in most wells. Increased natural hydrochemical background (Cl- and Na++K+ ions) has only been recorded in the shallowest well drilled in Dvorishchia village. The natural hydrochemical background of the water in intermorainic aquifers on the Belarusian side is 4 mg/l Cl- and 5.17 mg/l Na++K+. The amount of the two components in the well of Dvorishchia village is 9.9 and 35 mg/l respectively, and may be due to slight pollution resulting from man's activities.

On the territory of Belarus within a 10-km radius from the Ignalina NPP water is supplied to the population in a non-centralized manner from wells drilled in the uppermost non-confined aquifer (groundwater aquifer). Water from wells is used in all the villages and settlements in the area under consideration (Karasino, Nurviantsy, Mialka, Stankovichi, Minkovichi, Pashevichi, Podmuisa, Skutalishki, Yedogali, Drisviaty, Golevshchizna, Dobrody, Mamiany, Dvorishchia, Voilenishki, Nurviany, Gavrany, Grituny, Gireishi, Matseliany, Zatishye, Sestrentsy, Kardelishki). All in all, there are 200-odd wells. Shallow groundwater occurs in marginal moraines and fluvioglacial deposits (gt, gIIIbl, fII-Ibl). The water has been affected by man's activities. Increased amounts of NO3-, Cl-, SO42-, Na+ and K+ ions have been recorded in the wells. Data on water samples taken from the wells in Drisviaty village are characteristic of the water quality (Table 2). The amount of NO3- ions in the groundwater is as high as 140 mg/l, which is three times the limit set for drinking water (45 mg/l). It shows that the groundwater in the area is not protected against surface pollution.

8.1. Non-radiational impact on environmental components of neighbouring countries

The possibility of non-radiational impact on environmental and social components of the near-surface repository is assessed in subsection 4.2 of the present Report. It was shown that either no non-radiational impact is to be expected, or the impact would be minimal. The impact on environmental components (noise and dust during construction) can only occur on the construction site and its nearest environs, within a radius of some 300 m from the repository. Social impacts can only be felt on the territory of Lithuania. With the envisaged impact mitigation measures in place, the potential non-radiational impact on environmental and social components will be minimized. Therefore, there will be no non-radiational impact on environmental and social components of the Republic of Belarus and the Republic of Latvia, and they are not further analyzed in the present Report.

8.2. Effects of ionising radiation

The possibility of the effects of ionising radiation on environmental and social components is discussed in subsection 4.3 of the present Report. Whilst analyzing the possible effects of ionising radiation, all potential pathways of radionuclide dispersion and exposure, as well as their significance were assessed. The pathways of exposure will vary during different development stages of the repository. During the operation of the repository, packages containing solidified radioactive waste will be transported to the facility; therefore, radionuclides will not be released into the environment. However, packages with waste, packages temporarily stored in the facility, and those placed into the vaults of the repository before the facility is covered, will emit ionising radiation, and thus population can be subjected to external exposure of certain intensity.

Table 8.1. Geological and hydrogeological characteristics of artesian wells in Belarus

No.	Location	Date of drilling	Short description of geological section	Geological index	Thickness, m	Depth of floor, m	Water level, m	Settled water level, m	Rate of flow, l/s	Descent, m	Unit rate of flow, l/s
1.	Gavrany village, Braslav region, SW part of the village	1959	Sandy clay	gIIIbl	4	4					
			Clay with boulders	gIIIgr	30	34					
			Gravelly sediments with sand interbeds	f,lgIImd-IIIgr	6	40	34	8	4,2	7	0,6
			Clay	gIImd	7	47					
2.	Dvorishchia village, Braslav region, W part of the village	1966	Clay with boilders and gravel-cobble	gIIIgr	20	20					
			Fine sand	f,lgIImd-IIIgr	10	30	20	11	1) 1,9 2) 2,2	1) 4,0 2) 7,0	1) 0,4 2) 0,3
3.	Drisviary village, Braslav region, SW part of the village	1960	Till with gravel	gt,gIIIgr	0,3	0,2					
			Morainic clay	gt,gIIIgr	29,8	30					
			Till with gravel	gIIIgr+gIImd	72	102					
			Sand of variable size with gravel-cobble	f,lgIImd-žm	5,5	107,5	102	12	1) 3,3 2) 2,2	1) 13,0 2) 9,0	1) 0,2 2) 0,2
			Clay with boulders	gIIžm	2,5	110					
4.	Kardelishki village, Braslav region, W part of the village	1960	Fine sand	fIIIgr	4	4					
			Till with gravel	gIIIgr	8	12					
			Fine sand	gIIIgr	7	19					
			Till with gravel	gIIIgr	4	23					
			Coarse sand with gravel-cobble	gIIIgr	3	26					
			Till with gravel	gIIIgr	8	34					
			Fine sand	gIIIgr	6	40	34	6	1,7	17	0,1
			Till with gravel-cobble	gIIIgr	6	46					
5.	Latochki village, Braslav region, NW part of the village	1959	Soil		0,3	0,3					
			Till with gravel	gIIIgr	14,7	42					
			Silty sand	f,lgIImd-IIIgr	0,5	42,5					
			Till with gravel	gIImd	17,5	60					
			Sand with variable grain size	gIImd	1,5	61,5	60	N/A			
			Till	gIImd	5,5	67					
			Fine sand	f,lgIImd-žm	23	90	67	11	1) 1,2 2) 2,8	1) 4,5 2) 11,0	1) 0,3 2) 0,2

After the operation of the repository is discontinued, the repository will be closed. A multilayer cap of several meters thickness will be constructed over the repository, and there will be no direct effects of ionising radiation. However, it must be taken into consideration that long-lived radionuclides that did not yet decay in the long run may be leached into groundwater. In this case the impact caused by ionising radiation will depend on the properties and activities of the dispersed radionuclides, as well as the specific features of the site of the repository.

8.2.1. Exposure of population during the operation of the repository

The methodology described in subsection 4.3 was used for the purpose of the assessment of the exposure of residents of neighbouring countries resulting from the operation of the repository. It was conservatively assumed that a resident's external exposure is caused simultaneously by all potential sources of ionising radiation, such as the vaults of the repository, a radioactive waste package being loaded into the vault, the interim storage facility filled with waste packages, and another radioactive waste package being transported to the interim storage facility; Fig. 4.3.1.6. Equivalent doses were calculated with the MERCURY and SKYSHINE codes for a distance of 700 m from the vaults of the repository, which is the shortest distance between the repository and Lithuania's border with Belarus, if the facility is to be constructed at the Galilaukė site. The estimated annual external exposure dose for the population caused by all the sources of ionising radiation in the near-surface repository is summarized in Table 8.2. As can be seen from the table, the summary dose of external exposure will never exceed the exemption level of 10×10^{-3} mSv/year. Many conservative assumptions resulting in higher dose values were used in the estimates, viz. no consideration was given to the fact that the radiation sources are situated in a large area of the repository, and therefore their distance from the Belarusian border is different and exceeds 700 m, and that natural rises of the terrain, forests and other barriers would shield the radiation. It was also disregarded that the population most of the time stays indoors, in rooms that absorb ionising radiation. Therefore, the actual exposure doses of the population would be much lower.

Table 8.2. The maximum external exposure of population living at a distance of 700 m from the repository during the operation of the repository (the disposal of waste)

	From filled vaults	From an unshielded package	From the interim storage facility	From the package being transported	Sum total
Equivalent dose rate, mSv/h	9.68×10^{-7}	8.0×10^{-7}	3.36×10^{-9}	2.2×10^{-7}	
Duration of exposure, hrs per year	8760	150	8760	300	
Annual external dose, mSv	8.5×10^{-3}	1.2×10^{-4}	2.9×10^{-5}	6.6×10^{-5}	8.7×10^{-3}

The analysis of potential deviations of the operation shows that the worst situation may occur if a waste package falls and breaks down in the vault area (Chapter 7). In this case, residents of the critical group would be subjected not only to external exposure but also to exposure caused by emitted radioactive particles. Subsection 7.1 estimates that in this case the maximum effective dose will not exceed 1×10^{-4} mSv, whereas the equivalent dose rate at a distance of 700 m from the repository could be 5.6×10^{-6} mSv/h. Assuming that the effects of the accident are mitigated within 24 hours, the external exposure dose would not exceed 1.4×10^{-4} mSv. Thus, the exposure dose of the population at a distance of 700 m from the repository would not exceed 2.4×10^{-4} mSv, i.e. it would be lower than the exemption level ten-odd times.

The distance chosen for the estimates corresponds to the minimal distance from the Galilaukė site that lies the closest to the border with Belarus. Distances from the other two sites to Belarus, let alone Latvia, are several times longer. The dose rate rapidly decreases with the distance from the source of ionising radiation; therefore, detailed estimates of other cases make no sense In accordance with international standards of radiation safety (*Basic Safety ..., 1996,* and *International Basic ..., 1996*), an activity is not to be controlled in terms of radiation safety if the effective dose accumulated by any resident as a result of this activity does not exceed 1×10^{-2} mSv/year.

If the repository is constructed in any of the three sites, Apvardai, Galilaukė or Stabatiškė, during the operation of the repository population of the neighbouring countries, Belarus and Latvia, will never be subjected to significant effects of ionising radiation, i.e. the external dose will be many times lower than the background radiation level and will not exceed the exemption level.

8.2.2. Post-closure exposure of population

The most recent studies and estimates (*Selection of, ...2005* and *Motiejūnas S., ... 2005*) confirm that the engineering barriers envisaged in the reference design of the repository are very reliable, and thus within the first 300 years after waste disposal water will not percolate into the repository or leak from it into the environment. In other words, there will be no radioactive effluents. Over that time most radionuclides will decay, and the waste will no longer pose any hazard to the environment and population. However, in order to ascertain whether or not natural barriers are capable of replacing engineering barriers in the event the latter were inadequately constructed or damaged, and to compare the alternative sites in terms of safety, assessment was made based on the assumption that precipitation water penetrates the repository immediately after its closure (subsection 4.3).

APVARDAI SITE

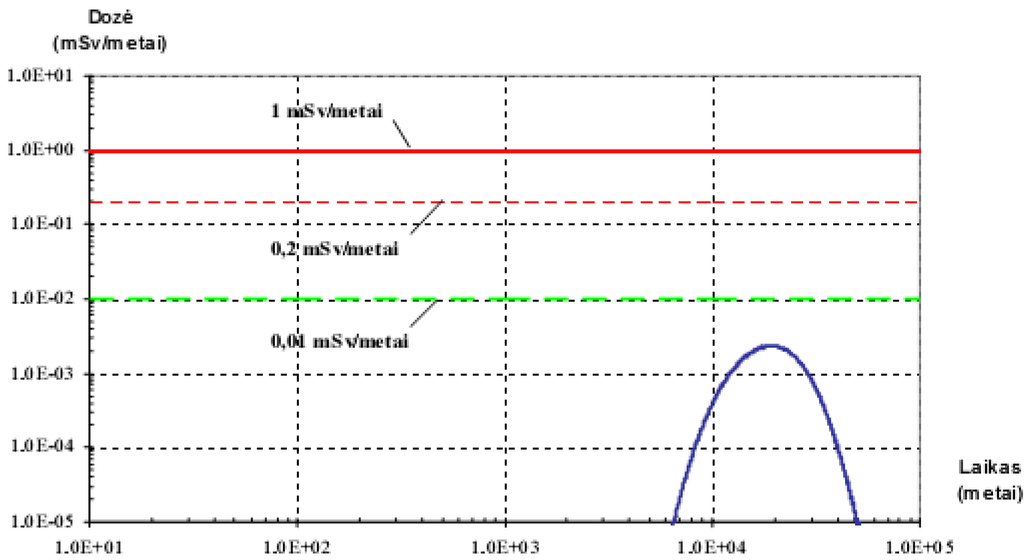
If the repository is constructed at the Apvardai site, the radionuclides leached from the facility would enter (with groundwater) Lake Apvardai along which the Lithuanian-Belarusian border runs. The maximum doses received by population of Belarus and Lithuania would be approximately the same. Subsection 4.3 shows that the maximum effective annual dose of the critical group of population (fishermen) living in the vicinity of Lake Apvardai would not exceed 0.009 mSv. The maximum annual dose received by Belarusian population could thus be close to the exemption level (0.010 mSv/year), i.e. the level which, if not exceeded, is not to be taken into consideration while assessing its impact on the environment and humans (*Basic Safety ..., 1996* and *International Basic ..., 1996*). This level amounts to just one hundredth of the dose constraint set by international organizations at 1 mSv/year.

Water flows from Lake Apvardai to Lake Drūkšiai. From the latter, it flows along the Drūkša and Dysna (in Belarus) rivers into the Daugava that winds through the Republic of Latvia. Before reaching the Daugava river, the water covers a long distance in Belarus. It is obvious, however, that due to lower specific volumic activities there will be much less radionuclides in this watercourse than in the water of Lake Apvardai. Therefore, the doses received by local population will also be lower than those to which people living near Lake Apvardai will be subjected. The peculiarities of radionuclide transfer in the Lake Drūkšiai–the Daugava river water route have been thoroughly analysed (*Mažeika J. and Motiejūnas S., 2002*). The results of this publication were used to assess the effects of ^{14}C radionuclides (short-lived radioactive waste can contain negligible amounts, referred to as traces, of these radionuclides) on Latvian population. Activities of radionuclides, including ^{14}C, in various surface water bodies were estimated based on data on radionuclide outflow into Lake Drūkšiai, using the PC CREAM 97 code. Individual effective doses were also calculated fishermen and their family members in the radionuclide dispersion route Lake Drūkšiai – the Prorva – the Drūkša – the Dysna- the Daugava – the Baltic Sea. Based on the results of this study it was determined that ^{14}C radionuclides of 1 Bq activity leached into Lake Drūkšiai, in the Daugava River (in the area of the border between Belarus and Latvia) would cause an effective dose of up to 2.5×10^{-17} Sv/year for the members of the critical group of the population.

Calculation of the potential dispersion of radionuclides from the near-surface repository showed that the maximum release of ^{14}C radionuclides into Lake Apvardai would amount to $2.26\text{x}10^{9}$ Bq/year or less. Intense water exchange (the annual transmissivity is approximately 218%; Table 4.3.2.5.) is characteristic of Lake Apvardai. If all ^{14}C radionuclides getting into Lake Apvardai are assumed to reach Lake Drūkšiai, it follows from the results of the publication (*Mažeika J. and Motiejūnas S., 2002*) that the effective dose for the critical group of Latvian population would not exceed $5.7\text{x}10^{-5}$ mSv/year. The population in the vicinity of Lake Apvardai would receive lower doses from other radionuclides, and their effects on Latvian population would be even less palpable. Therefore, if the near-surface repository is constructed at Apvardai site the effective dose received by a member of the critical group from all waterborne radionuclides would not exceed $6\text{x}10^{-5}$ mSv/year. The exposure dose of Latvian population would be 100-odd times less than the exemption level.

GALILAUKĖ SITE

If the repository is constructed at the Galilaukė site, the radionuclides emitting from its vaults would be transferred downwards to the first semi-confined-confined aquifer. Radionuclides would not be dispersed horizontally in the Galilaukė hill at all, or only negligibly. The latest studies of the proposed site show that the water of the first semi-confined-confined aquifer flows northwards, i.e. not towards the valley of the Daugava river. Therefore, the radionuclides scattered from the repository will not have any effect on Belarus. While estimating the dispersion of ^{14}C radionuclides (the effect of other radionuclides will be much lower) northwards, the aquifer in the hill of the repository's site was assumed to stretch to the border with Latvia 11 km away, and the groundwater was assumed to flow towards Latvia. It was conservatively assumed that the properties of the aquifer do not change, that this aquifer is not connected to any other aquifers, it is not recharged by other aquifers and does not discharge into surface water bodies. The coefficient of longitudinal dispersion was assumed at 1100 m (1/10 of the distance of dispersion). The potential transversal dispersion was conservatively disregarded. Other parameters of the aquifer are given in Table 4.3.2.4. . The DUST and GWSCREEN codes were used to calculate the dispersion of ^{14}C radionuclide to Latvia and the exposure caused by it (subsection 4.3). The results are shown in Fig. 8.4.



Dozė	Dose
mSv/metai	mSv/year
Laikas (metai)	Time (year)

Fig. 8.4 Changes in effective doses received as a result of ^{14}C radionuclide dispersion from the Galilaukė site calculated for the scenario of degradation of repository's engineering barriers if groundwater enters a bore (well) drilled 11 km away from vaults of the repository (at the Lithuanian–Latvian border).

The maximum effective annual dose on the territory of Latvia caused by the dispersion of ^{14}C radionuclide calculated for the biosphere bore model is $2.4x10^{-3}$ mSv. . The share of all other radionuclides is virtually nil. As can be seen from Table 8.2, the effective dose from other radionuclides in the immediate vicinity of the repository does not exceed $8.3x10^{-4}$ mSv/year. The effect on the population of neighbouring countries will be still lower; therefore, it makes no sense to analyse it. The potential exposure dose of Latvian population is more than some 3 times lower than the exemption level.

STABATIŠKĖ SITE

The location of the Stabatiškė site is quite similar to that of the Apvardai site. It also lies a short distance away from Lake Drūkšiai that is divided by the Lithuanian–Belarusian border. Two pathways of radionuclide transfer were analyzed, with intermorainic groundwater and with surface water. In both cases water enters Lake Drūkšiai. However, in the case of radionuclides reaching the lake with surface water, the impact is more significant (subsection 4.3.2.). Therefore, the surface water pathway was conservatively chosen. In this case the maximum dose of the critical group of population (fishermen) is 0.009 mSv/year, i.e. it does not exceed the exemption level. The effects of radionuclides getting into Lake Drūkšiai with surface water would be the same for fishermen of Belarus and Lithuania.

The exposure pathway of Latvian population would only negligibly differ from the analysed exposure pathway in the case of the Apvardai site. In this case the exposure dose of Latvian population would be 100-odd times less than the exemption level and is therefore not estimated in detail.

8.3. Conclusions

The following conclusions can be drawn after generalizing the assessment of the impacts of the planned economic activities on neighbouring countries:

1. Non-radiational impact on environmental and social components can only be

expected in the immediate vicinity of the repository. Environmental and social components of neighbouring countries will not be affected.

2. If the repository is constructed in any of the three alternative sites, Apvardai, Galilaukė or Stabatiškė, population of the Republic of Latvia will not be affected by ionising radiation, as the potential maximum exposure dose will be lower than the exemption level.

3. If the repository is constructed in any of the three alternative sites, Apvardai, Galilaukė or Stabatiškė, population of the Republic of Belarus will not be affected by ionising radiation, as the potential maximum exposure dose will not exceed the exemption level.

9. PUBLIC PARTICIPATION AND THE EVALUATION OF THE EIA REPORT

The EIA Report (*4th edition, date of issue: 2005*) pertaining to the near-surface repository and analysing two sites (the Apvardai site and the Galilaukė site) was co-ordinated with all environmental impact assessment entities in 2005. The Radiation Protection Centre (RPC) contacted Swedish experts of technical support requesting to assess the presented environmental impact report. Responses to the notes of the RPC are provided in Annex 4 to Part Two of the EIA Report (4th edition) dated 14 March 2005.

Based on the recommendations of the Lithuanian Nuclear Safety Advisory Committee, the analysis of the third alternative site, i.e. the Stabatiškė site, located near the Ignalina NPP in Visaginas Municipality commenced in 2005. The results are summarised in the supplemented EIA Report for the construction of a near-surface repository for radioactive waste.

In December of 2005, the independent expert examination carried out by the IAEA gave a favourable assessment of the programme implemented by the RATA. Conclusions and recommendations of experts are provided in the report of the said mission (*An international* ..., 2006), which can be found on the website of the IAEA: http://www-pub.iaea.org/MTCD/publications/PubDetails.asp?pubId=7613. With the help of Lithuanian experts the recommendations have been analysed and assessed, and a plan to implement them has been developed (*Paviršinio radioaktyviųjų atliekų ..., 2006*). Recommendations have been divided into groups: some of them have become irrelevant, and the rest will have to be considered in later stages of project implementation. Lithuanian experts agreed with the authors of the conceptual design of the repository (*Reference design ..., 2002*) that it was not worth to construct monitoring galleries under the vaults of the repository, as this would significantly reduce the reliability of the disposal system. The monitoring of the repository is proposed to be carried out by other means. To demonstrate the reliability of the barriers of the repository, international and Lithuanian experts suggest (*An international* ..., 2006; Paviršinio radioaktyviųjų *atliekų ..., 2006*) to construct a pilot model and to carry out long-term monitoring. The necessity of such monitoring was also indicated by the Belarusian authorities.

The results of geological and hydrogeological analysis performed in the Stabatiškė site in 2006 were reviewed and assessed by experts of the VATESI as well as Lithuanian and international experts (SKI (Sweden), RISKAUDIT IRSN (France), AVN (Belgium), the Institute of Physics and Kaunas University of Technology). The results were discussed in Vilnius on 11 July 2006; the work performed by the RATA and its subcontractors was evaluated, and it was noted that adequate models were used for the description of the Stabatiškė site and for the simulation of processes. The co-operation of the authorised body (VATESI) and the RATA has received favourable assessment.

31 July 2006 saw the publishing of a supplemented environmental impact assessment report for the construction of a near-surface repository for radioactive waste; the report was presented to the public following the procedure prescribed by the legislation (*Planuojamos ūkinės veiklos..., 2000, Visuomenės informavimo..., 2005*). Information about the available EIA report and about the intended public presentation of this report was announced in *Mūsų Ignalina* newspaper (No. 62(170)) on 22 June 2006, in newspapers *Lietuvos rytas* (No. 191) and *Naujoji vaga* (No. 63(6851) on 23 June 2006, and in *Sugardas* newspaper (No. 34(605)) on 24 June 2006, also on the website of the State Enterprise Radioactive Waste Management Agency (RATA) more than 10 days prior to the intended meeting with the public. Announcements on the availability of the report and the intended public presentation of this report appeared on bulletin boards of the Municipality of Ignalina Region, Rimšė Neighbourhood of Ignalina Region and Visaginas Municipality on 24 June

2006. Announcements stated the location and the nature of the planned economic activity, the organiser of this economic activity, the venue and time when information about this planned economic activity may be obtained, the contact person for submission of proposals regarding the environmental impact assessment related to the planned activity. The supplemented EIA report was available for scrutiny at the Municipality of Ignalina Region, Rimšė Neighbourhood of Ignalina Region and the Radioactive Waste Management Agency (Vilnius). The electronic version of the supplemented EIA report was announced on the website of the RATA (www.rata.lt). Copies of public announcements are presented in Annex 3 to this Report.

The public presentation and discussion of the supplemented EIA Report took place on 7 September 2006 in Visaginas, in the conference hall of *Aukštaitija* Hotel, at the time convenient for the public (after working hours). The supplemented EIA Report was presented to the public (Fig. 9.1) according to the established procedure. During the meeting the planned economic activity was described, the supplemented EIA Report pertaining to the planned economic activity was presented to the public, which was followed by the question and answer session. No motivated public proposals regarding the supplemented EIA Report were received before the start of the meeting. The meeting caught the attention of the media and some individuals, there were some questions asked; however, no motivated public proposals regarding the supplemented EIA Report were received, either prior to the meeting or after the meeting. Therefore, the supplemented EIA Report presented to the public did not require any revision. The public was acquainted with the minutes of the public meeting (provided in Annex 3 to this Report).

Fig. 9.1 The presentation of the supplemented EIA Report in Visaginas on 7 September 2006.

The supplemented EIA report for the construction of a near-surface repository for radioactive waste was prepared with due consideration to notes submitted by environmental impact assessment entities following the procedure provided by the legislations (*Planuojamos ūkinės veiklos..., 2000*). Version 2-1 of the supplemented EIA Report was submitted for co-ordination to the following authorities on 21 September 2006: Utena Regional Environmental Protection Department of the Ministry of Environment, the Radiation Protection Centre of the Ministry of Health, Utena Public Health Centre of the Ministry of Health, Utena County Governor's Administration, Visaginas Municipality, Ignalina Region Municipality, Fire and Rescue Services of Visaginas and for the protection of the Ignalina NPP of the Fire and Rescue Department, Ignalina Fire and Rescue Service of the Fire and Rescue Department, and Utena Territorial Unit of the Department of Protection of Cultural Values. Comments have been provided only by the Radiation Protection Centre, Utena Territorial Unit of the Department of Protection of Cultural Values under the Ministry of Culture, and the Council of

Ignalina Region Municipality. The remaining authorities approved the report without providing any comment (Annex 4).

The RPC commented on the structure of the report and the quotation of documents. Due consideration was given to all the comments in Version 3 of the supplemented EIA Report.

Utena Territorial Unit of the Department of Protection of Cultural Values under the Ministry of Culture indicated that a site of an estate was detected in Stabatiškė in June of 2006. The findings are dating from approximately the end of the 18th C – the 20th C. Therefore, the EIA Report should provide for the measures to preserve this object. The RATA commissioned additional exploratory archaeological studies; the results of these studies supplemented respective chapters of this Report.

The Council of Ignalina Region Municipality did not approve the said report on the environmental impact assessment (Resolution No. 827 of 31 October 2006) and proposed to analyse the impact on social and economic environment in greater detail as well as to provide for measures to offset such impact. In 2004, the RATA received a similar requirement when it was co-ordinating the EIA report for the Galilaukė and the Apvardai sites; therefore, it commissioned study "Assessment of the Demand for and the Nature of Social Compensatory Measures and the Infrastructure Development in the Area of the Proposed Near-Surface Repository". With due consideration to the potential impact, the study assessed the demand for compensatory measures. The municipal administration of Ignalina Region has been acquainted with the results of the study. As the supplemented environmental impact assessment report for the construction of a near-surface repository for radioactive waste provides a detail analysis of potential social and economic impacts that is in line with the Environmental Impact Assessment Programme for Construction of a Near-Surface Repository approved by the Ministry of Environment, and in the absence of the motivation of these additional studies, the said studies were not repeatedly performed, the more especially as the administration of the closes municipality; viz. Visaginas Municipality, did not raise any similar issues.

Considering the conclusion of the Ministry of Environment regarding the necessity of environmental impact report in a transboundary context, the EIA Report was supplemented with Chapter "Possible transboundary impact" (Chapter 8), which was not included into the EIA programme. It has been translated to Russian and English. On 11 October 2006, the supplemented EIA Report was submitted to the Ministry of Environment of the Republic of Lithuania for the identification of possible transboundary impact. According to the provisions of the Espoo Convention, consultations with the neighbouring states were held. In December 2006, the RATA presented the environmental impact assessment results to the public of Latvia and Belarus (Fig. 9.2 and 9.3). Comments received from the neighbouring states are presented in Annex 5. These comments and proposals were thoroughly analysed and evaluated. Respective chapters have been supplemented or amended during the preparation ov Versions 3-1 and 3-2 of this EIA Report. The proposal to carry out the repository surveillance for more than 300 years and to construct the model of engineering barriers has been accepted. Furthermore, proposals to extend the environmental monitoring to include the territories of the neighbouring states and to intensify the dissemination of information about the waste handling safety have been accepted.

However, the Belarusian proposal to construct a waste storage facility instead of the repository was rejected, as this proposal conflicts with the key provisions of the Joint Convention on the Safety of Spent Fuel and on the Safety of Radioactive Waste Management and the principles of radioactive waste management. As the final disposal of short-lived radioactive waste in near-surface repositories is a common practice, the inheritance of such undeserved burden by future generations would be completely unjustified.

Belarus holds that the Stabatiškė site is the safest site of the three for the construction of the repository. Belarusian specialists and the public categorically oppose the construction of the repository in the Galilaukė site. Respective chapters of this Report have been amended with due consideration to the comments of the aforementioned parties.

Fig. 9.2 The presentation of the EIA in Daugavpils on 12 December 2006.

Fig. 9.3 The presentation of the EIA in Braslav, Belarus, on 21 December 2006.

10. DESCRIPTION OF PROBLEMS

During the environmental impact assessment related to the planned economic activities, viz., during the development of the programme and of the report, the failure of some EIA entities to meet the established deadlines was the key problem. The Council of Ignalina Region raised ungrounded requirements. Demands of neighbouring countries for compensations are of a political rather than technical nature.

REFERENCES

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ANNEXES

TO THE ENVIRONMENTAL IMPACT ASSESSMENT REPORT FOR CONSTRUCTION OF A NEAR-SURFACE REPOSITORY FOR RADIOACTIVE WASTE