ENVIRONMENT IMPACT ASSESSMENT REPORT ON

INVESTMENT PROPOSAL

CONSTRUCTION OF NATIONAL DISPOSAL FACILITY FOR LOW AND INTERMEDIATE LEVEL RADIOACTIVE WASTE – NDF

PART II

ALTERNATIVES TO PROPOSED TECHNOLOGIES AND THE REASONS FOR THE SELECTION

Sofia, January 2015

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2 ALTERNATIVES TO PROPOSED TECHNOLOGIES AND THE REASONS FOR THE SELECTION

2.1 ZERO ALTERNATIVE

The Zero alternative or decision not to be taken any actions for implementation of the investment proposal means a refusal a NDF to be constructed in the country in near future.

Currently, the radioactive waste which has been received by the operation of Unit 5 and 6 of Kozloduy NPP and accumulated historical radioactive waste are processed in the facilities of SU RAW-Kozloduy. The conditioned waste is stored at Warehouse for storage of conditioned RAW that has a capacity of 1920 RCC. The conditioned radioactive waste from decommissioning of Unit 1÷4 of Kozloduy NPP shall be stored at the warehouse.

The capacity of the warehouse is designed in view of the fact that it is an intermediate unit in the overall system for radioactive waste management in accordance with the requirements of the Bulgarian nuclear legislation[1,2], safety standards of IAEA[3,4,5,6], Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management[7] and Council Directive 2011/70/Euratom of 19 July 2011 on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste[8].

The warehouse is a facility for temporary storage of RAW before its burial in the NDF and its design lifetime is 50 years. Currently, 1368 RCC are stored in the warehouse. Having in mind the rate of filling the warehouse with conditioned radioactive waste which is identified by the production requirements to ensure normal operation of Unit 5and 6 of Kozloduy NPP and normal process of decommissioning of Unit 1÷4 of Kozloduy NPP, its storage capacity shall be spent in less than 4 years.

The Zero alternative, i.e. the refusal a NDF to be constructed, has been rejected directly because:

- → it **is not in compliance with** nuclear legislation according to which radioactive waste should be buried as soon as possible after its generation;
- → it **is not in compliance with** the requirements of Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management[9];
- → it **is not in compliance with** the legislation of the European Union - Council Directive 2011/70/Euratom of 19 July 2011 on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste[10], as well as Act on the

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[1] Act on the safe use of nuclear energy, Prom. SG No 63/28.06.2002, last amended SG No 68/02.08.2013

[2] Ordinance on safe management of radioactive waste SG No 76/30.08.2013

[3] IAEA, Fundamental Safety Principles, Safety Fundamentals No.SF-1, IAEA, 2006

[4] IAEA, The Principles of Radioactive Waste Management, Safety Standard Series No.111-F, IAEA, 1995

[5] IAEA, Storage of Radioactive Waste, Safety Standards, Safety Guide No.WS-G-6.1, 2006

[6] IAEA, Predisposal Management of Radioactive Waste, Safety Standards, No. GSR part 5, 2009

[7] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Ratified by a law approved by 38th National Assembly on 10.05.2000, SG No 42/23.05.2000

[8] Council Directive 2011/70/Euratom of 19 July 2011 on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste

[9] Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. Ratified by a law approved by 38th National Assembly on 10.05.2000, SG No 42/23.05.2000

[10] Council Directive 2011/70/Euratom of 19 July 2011 on establishing a Community framework for the responsible and safe management of spent fuel and radioactive waste

safe use of nuclear energy[11] and Strategy for the Management of Spent Nuclear Fuel and Radioactive Waste[12]

→ it **is not in compliance with** the decisions of the government of Republic of Bulgaria**:**

- Strategy for the Management of Spent Nuclear Fuel and Radioactive Waste until 2030, accepted by Decision of the Council of Ministers on 05.01.2011 according to which the construction of the NDF is the highest priority;
- Decision of the Council of Ministers No 683 of 25 July 2005, SE RAW has been awarded to construct a national repository for burial of radioactive waste[13];
- Decision of the Council of Ministers № 898 of 8 December 2011. The National repository, for which construction as a part of procedure related to the identification of location of nuclear facility is selected Radiana site, is determined for a national site under State Property Act and as a site of national importance under the Spatial Planning Act[14];
- Council of Ministers Decree No 3 of 10 January 2013, the national repository is identified as a strategic site for the national security[15].

The Zero alternative i.e., the refusal a NDF to be constructed, leads to the following negative consequences:

(1) **Stopping the process of conditioning of RAW of the operation Unit 5 and 6** of Kozloduy NPP**.** In this case the temporary capacity for storing unprocessed radioactive waste from the operation of Kozloduy NPP shall be also exhausted and the operation of Unit 5 and 6 shall stop too. This shall have significant socio-economic consequences on population and industry in the country which shall result in significant increase of the price of electricity due to dropping out cheap electricity from Kozloduy NPP from the energy mix.

(2) Programme to extend period of operation of Unit 5 and 6 of Kozloduy NPP could not be fulfilled due to impossibility to provide long-term management of radioactive waste which shall be generated during the operation of the units. The socio-economic consequences are analogical to the above-mentioned.

(3) Stopping the decommissioning process for units 1÷4 of Kozloduy NPP because of lack of capacity for temporary storage of conditioned radioactive waste and lack of capacity for its burial. It should be emphasized that the stopping and decommissioning of Units 1÷4 of Kozloduy NPP is part of the Bulgarian EU accession treaty. In order to implement the decommissioning process, Bulgaria is financed by “Kozloduy” International Fund. Any default of the country shall lead to significant financial penalties.

(4) **Impossibility to construct new nuclear capacities.** The construction of new nuclear capacities is subject to approval by the European Commission. A significant condition is the presence of repository for burial of radioactive waste that shall be generated during the operation of the new nuclear capacity.

The non-implementation of the investment proposal **creates significant risks** for:

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[11] Act on the safe use of nuclear energy, Prom. SG No 63/28.06.2002, last amended SG No 68/02.08.2013

[12] Strategy for the Management of Spent Nuclear Fuel and Radioactive Waste until 2030, accepted by Decision of the Council of Ministers on 05.01.2011, amended by Decision of the Council of Ministers 25.06.2014.

[13] Decision of Council of Ministers №683/25.07.2005 for construction of a National repository for burial of radioactive waste

[14] Decision of Council of Ministers №898/08.12.2011for identification of NDF as a national site and site of national importance

[15] Council of Ministers Decree №3/10.01.2013 for amendment of Decree № 181 of council of Ministers of 2009 on identification of strategic sites and activities which are related to the national security

- → **health** of personnel of Kozloduy NPP, personnel of SE RAW and population in the surrounding settlements – the town of Kozloduy, the town of Miziya, the villages of Harlets, Glozhene, Butan, Kriva bara, etc.;
- → **Environmental condition** which could be expressed in pollution due to the presence of radionuclides in soil and near-surface area as well as groundwater mainly groundwater body “Pore water in Quaternary - Kozloduy Valley” under the code of BG1G0000Qal005 whose water is abstracted by means of water abstraction facilities constructed and it is a water protection area for domestic-drinking water supply.

On the basis of the above-mentioned, the zero alternative has been rejected. In order to implement the NDF, the Radiana site has been selected after years of researches made on different terrains in the country. The rationale on the selection of the location for IP for the NDF has been specified in chapter 1 of the present report. The selection of Radiana site as the most suitable in comparison to the alternative sites Brestova padina, Marichin valog and Varbitsa has been grounded in detail from p.47 to p.106. Moreover, a Detailed Development Plan - Regulation & Building Plan approved and effected by an order of the Minister of Regional Development and Public Works has been prepared for Radiana site. After a Decision of Council of Ministers №393/5.07.2013, the properties located on the Radiana site have been provided to SE RAW and they are its property. In view of avoiding repetition in this chapter, the emphasis has been put on technologies for burial of RAW.

2.2 ALTERNATIVE ACCORDING TO TECHNOLOGY OF BURIAL OF RAW

Two technologies for burial of low- and intermediate-level RAW category 2a in a modular near-surface multi-barrier engineering repository have been studied: trench-type[16] and tunnel-type[17]. Geomorphology at Radiana site provides two alternatives for disposal of the NDF:

- → Construction of a trench-type and tunnel-type repository within the borders of terrace T_6 – sloped section;
- → Construction of a trench-type repository in the lower flat part of the site within the borders of terrace T_2 – flat section.

The alternative for disposal of NDF within the boundaries of T6 – sloped section has been chosen as more expedient of those two alternatives and preventing to greater extent the migration of the radionuclides in geosphere during the institutional control.

Two technologies for burial of RAW in terms of safety and potential environmental impact have been analysed in the REIA.

2.2.1 TECHNOLOGY FOR BURIAL OF LOW- AND INTERMEDIATE-LEVEL RAW IN TRENCHES

2.2.1.1 STRUCTURE OF TRENCH-TYPE REPOSITORY

The repository shall be situated in depth of 35 m. under the original surface of the terrain on consolidated Pliocene clay which are significantly deep and located on elevations between 50.9 m. and 52.6 m. The disposition of the repository in the geological section is given on **Figure 2.2-1.**

The repository consists of sixty-six (66) cells for burial of radioactive waste packages, it is situated on 3 identical platforms and each of them includes twenty-two (22) cells. The disposal cells are located in two rows, each of them having eleven cells. The capacity of each disposal platform is 6336 RCC and the capacity of each cell is 288 RCC.

[16] Project: National repository for burial of radioactive waste at Radiana site, Consortium Westinghouse Electric Spain, DBE Technology, Enresa, 2014

[17] Feasibility study for construction of NDF, a tunnel-type repository, Minproekt EAD, 2009

The disposal cells are monolithic rectangular reinforced concrete structures and external dimensions of each cell are 20.15 m length and 17.05 m width. The height is 9.45 m, measured from the level of the foundations to the top of the roof slab. Each disposal cell is divided by 2 parallel internal walls into 3 chambers whose internal dimensions are 6.05 m / 16.05 m and they can contain 96 RCC each. The reinforced concrete containers are arranged in 4 rows one on top of the other. Each chamber holds 8x3 RCC in plan and 4 rows one on top of the other and each cell holds totally 8x9 RCC in plan in 4 rows one on top of the other.

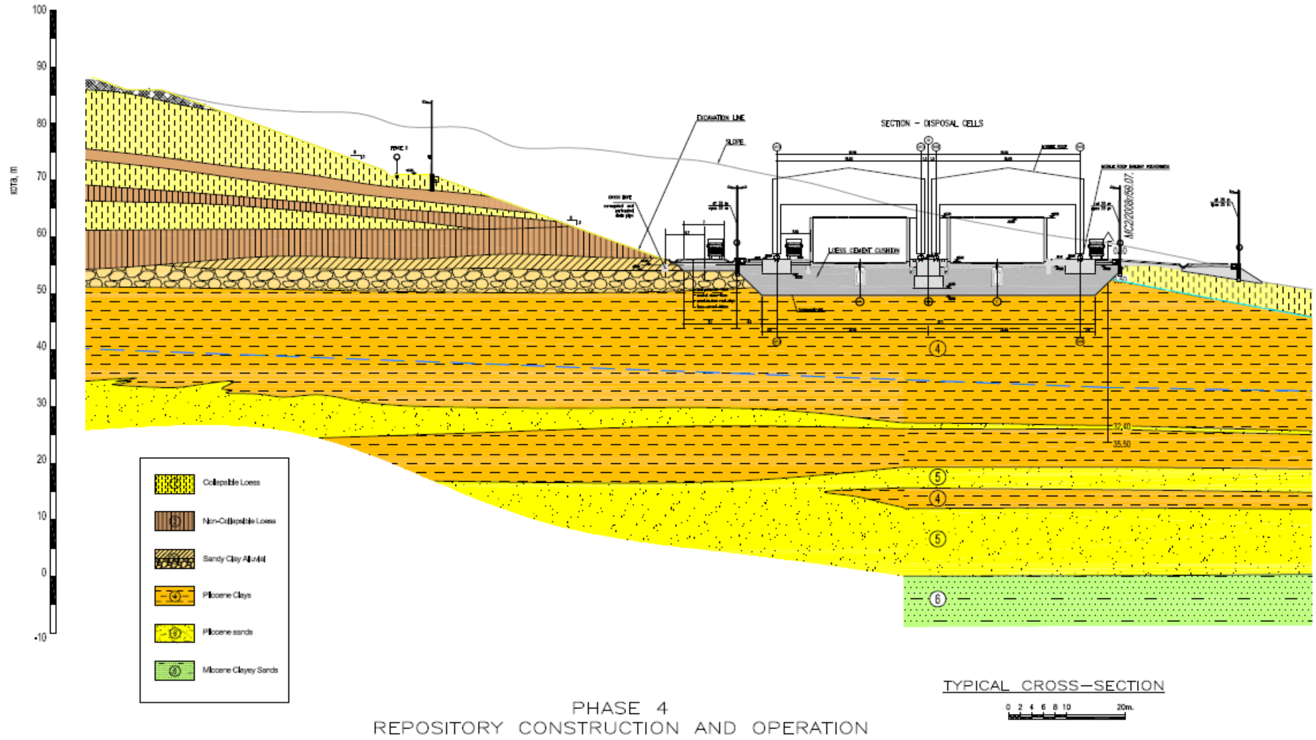

FIGURE 2.2-1 GEOLOGICAL CROSS SECTION OF LOCATION OF A TRENCH-TYPE REPOSITORY

The cells are constructed on loess-cement cushion which is 5 m. thick, located between elevations +50 m. and +55 m. The loess-cement cushion is thicker – 6.3 m. sideways of the disposal cells in order to cover the edges of the base plate (from elevation +50 m. to elevation +56.3 m.) the loess-cement cushion has been designed:

(1) To fulfil the requirements for strength and deformability and increasing the load capacity of the system and reducing the relative subsidence;

(2) To increase the thickness of unsaturated zone;

(3) To be constructed drainage galleries in it under each parallel row of disposal cells.

The cells of the repository have been designed as individual cells – structurally independent without having any structure connection between them. The clearance between two cells in one row is 1.20 m.

The foundation slab is 0.60 m. thick. The external and internal walls are 0.50 m. thick and the roof slab is 0.60 m. thick. **Figure 2.2-2** is an illustration of the national trench-type repository.

The empty cells of the repository before the disposal of waste in them are protected of weather conditions by installation of roof panels - 0.25 m thick and 1.99 wide, which are water-resistant.

Thus, protected cells shall remain unchanged from their construction to the start of their filling i.e. during the entire period which they can stay empty – 20 years. Control and maintenance of waterproofing is envisaged.

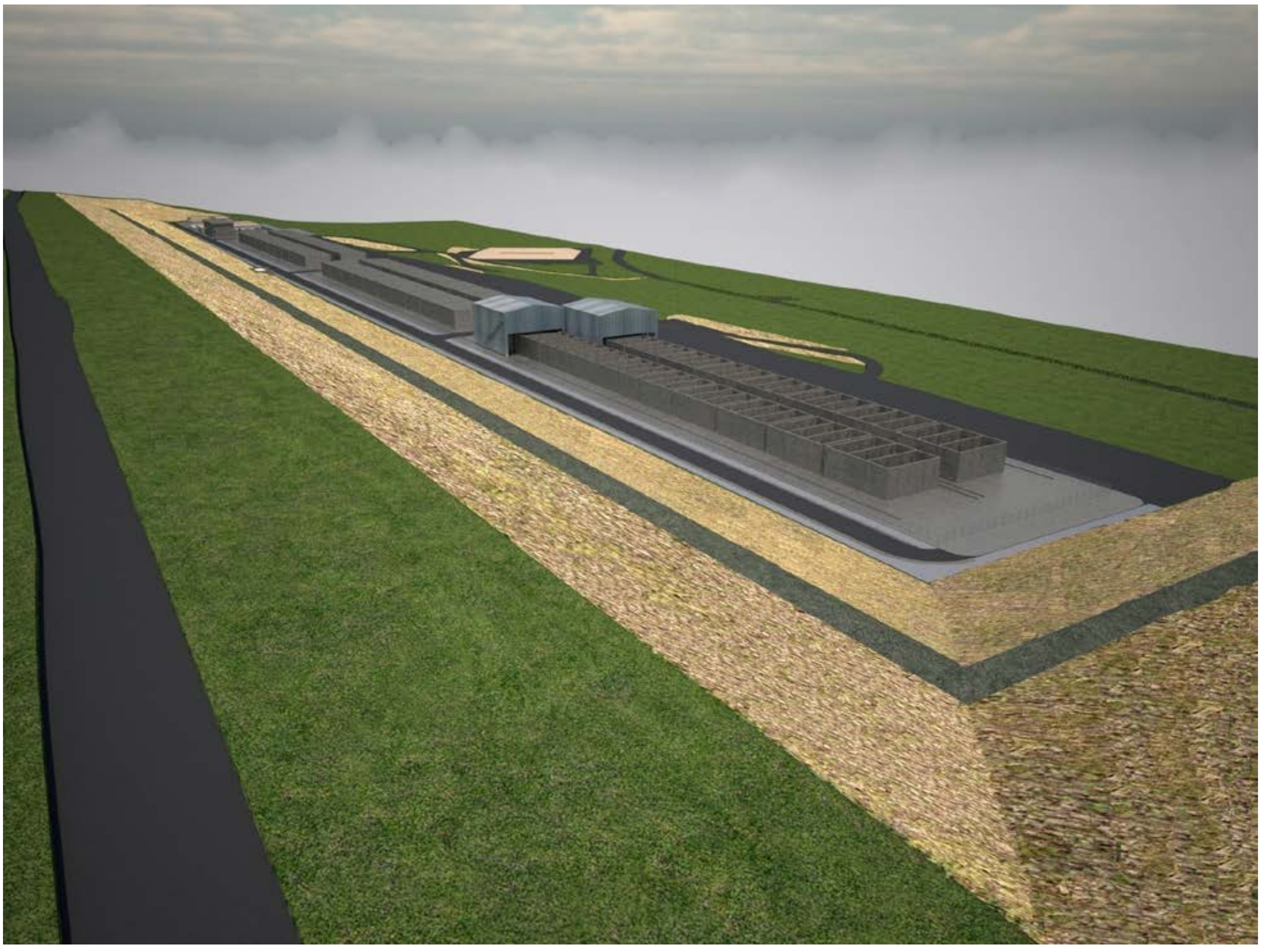

FIGURE 2.2-2 EXTERIOR OF A TRENCH-TYPE NDF

After the disposal of four rows of containers, the cell is covered with identical roof panels. A monolithic reinforced concrete roof slab – 0.60 thick which is water-resistant.

The bottom plate is designed to let water which has penetrated into the construction to be collected and taken away through the network for control of infiltrated water. In each chamber the bottom plate has a slope to the central point of runoff. It is covered with an equalizing layer of porous concrete, on top of which radioactive waste packages are placed.

Each cell is protected by a sliding (retractable) roof until it is being filled in. The sliding roof allows the RAW packages to be protected from stormwater before the closing roof slab to be put on. There are two sliding roofs one for each row of cells as the one is used during the filling of the cell with radioactive waste and the other during the covering of the filled cell with roof panels and construction of the roof slab. Each of them has an overhead crane which moves along the sliding roof.

The overhead crane is designed to transport RCC with maximum weight of 20 t. plus the weight of handling equipment. The design load of the crane is 40 t which includes an additional coefficient of reserve. It is designed to operate at least 60 years. The basic location of the sliding roofs is given on

Figure 2.2-3. The sliding roof covers the entire cell which is serviced at the moment as well as the unloading area used by the special transport vehicle for radioactive waste.

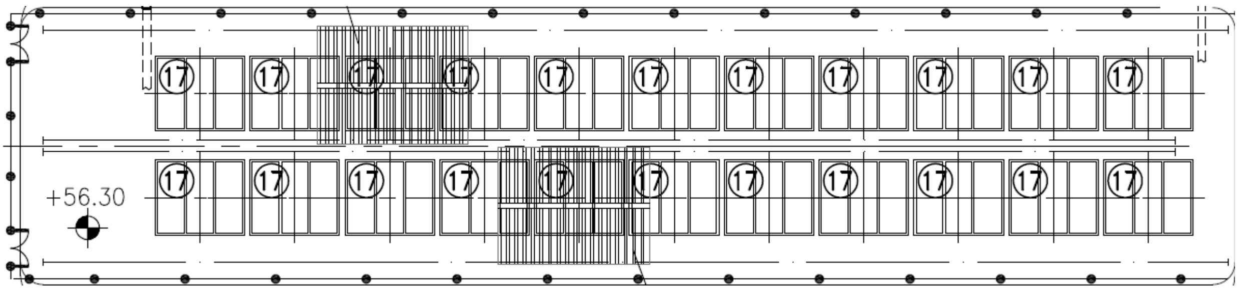

FIGURE 2.2-3 GENERAL LOCATION OF SLIDING ROOFS

The sliding roof is metal construction made of steel S355 J2 type similar to that one used for the warehouse which is driven by rail from full to empty cell in the repository. It is painted with protective coating to prevent corrosion during operation. Its dimensions are 24.65 m x 30 m between the axes of the external columns and the maximum height is 19.7 m. The construction is supplied with an external ladder for inspection from the external side and internal platform for inspection located between the construction of the sliding roof and the cell of the repository when the sliding roof is situated above the cell of the repository - **Figure 2.2-4**.

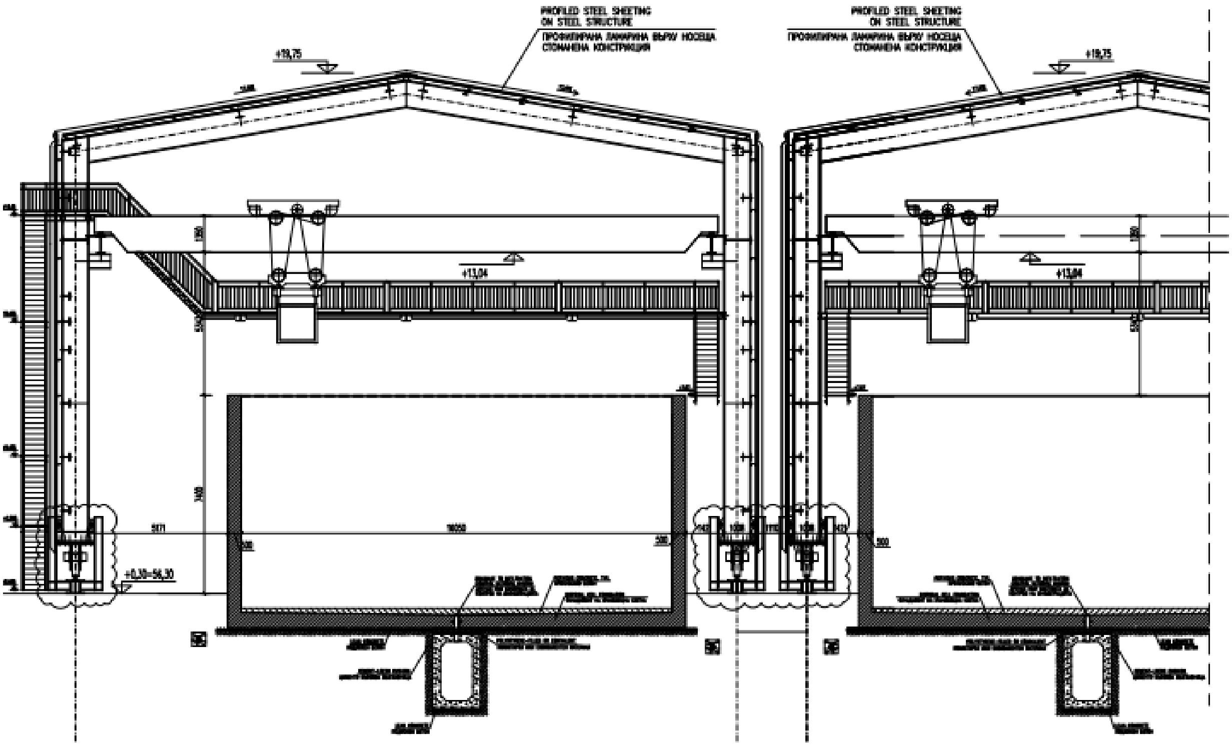

FIGURE 2.2-4 SLIDING PROTECTIVE ROOF - CROSS SECTION

According to the design, the cells of the repository are constructed of concrete class C35/45 under BNS EN 1992-1-1[18] and BNS EN 206-1[19] with reinforcing steel B500B under BNS EN 10080[20]

[18] BNS EN 1992-1-1, Eurocode 2 Design of concrete and reinforced concrete structures

[19] BNS EN 206-1:2002 Concrete – Part 1: Specification, performance, production and conformity. БДС EN 206-1/NA:2008 National Annex to BDS EN 206-1:2002

and they are designed for the entire lifetime of the National repository – the design lifetime is 375 years.

The loess-cement cushion and construction of the repository are designed according to the load determined by the buried reinforced concrete containers, the reinforced concrete constructions of the repository plus loads during the different periods of the lifetime of the repository – the load determined by the steel warehouse and 40-ton crane during the lifetime; the load determined by the construction of the protective multi-barrier coating and backfilling until restoring the original terrain of Radiana site. The authors of the design have proved that the maximum subsidence amounts to just 10-12 cm. It has been proved by means of two independent calculation methods which are established in practice as well as on the basis of reverse analysis on the measured subsidence of the ground base of Units 5 and 6 of Kozloduy NPP.

The general layout of a trench-type repository is given in **Figure 2.2-5** and **Appendix 8-II.1**.

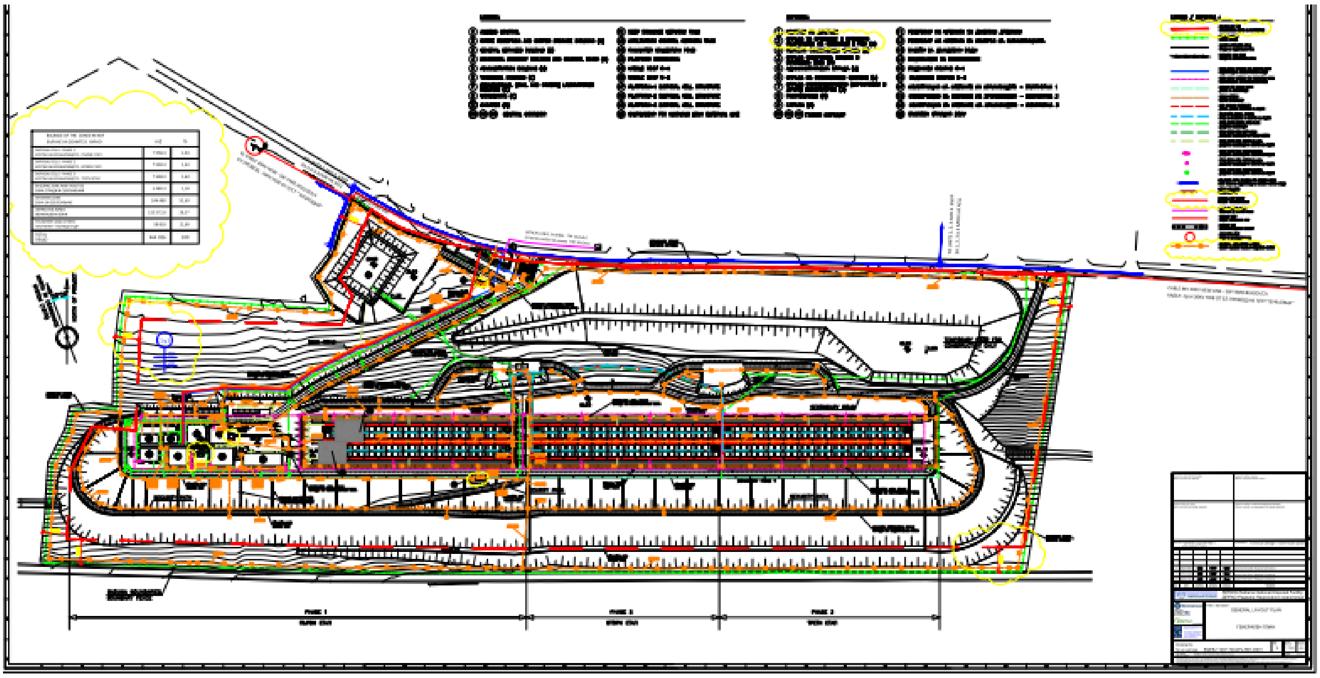

FIGURE 2.2-5 GENERAL LAYOUT OF NDF AT RADIANA SITE

2.2.1.2 REPOSITORY CAPACITY

The trench-type repository consists of three platforms as each of them is constructed of 22 cells which hold 288 radioactive waste packages. The capacity of each platform is 6336 RCC.

Total repository capacity is 19 008 RCC. The trench-type repository capacity identified in the design conforms to the requirements for the capacity of NDF specified in part 1.7.3 of Chapter 1.

2.2.1.3 AUXILIARY BUILDINGS AND FACILITIES

The auxiliary buildings and facilities include technological facilities for radioactive waste management and service buildings and facilities which in general are identical for two technologies for burial of radioactive waste and they are specified in chapter 1.

[20] BNS EN 10080:2005 Steel for the reinforcement of concrete - Weldable reinforcing steel - General

The activity during the production of above-mentioned roof panels which does not require an individual building or facilities except the standard control laboratory is specific for the technology for burial of radioactive waste in a trench-type repository.

2.2.1.4 NECESSARY AREA AT RADIANA SITE

According to the authors of the paper, the total area which should be fenced for the needs of a trench-type repository is 46.4 hectare.

In accordance with the requirements of the nuclear legislation, the entire Radiana site shall be considered as a site of nuclear facility where the requirements for physical protection and rules and standards for provision of fire safety of nuclear facilities[21,22] shall be applied. A system of fence facilities – warning, retarding and stopping fences equipped with technical devices for control and video surveillance shall be constructed. Before the construction, the site shall be cleared up from the existing trees and lower bushes. A drainage system for surface water - channels with rectangular sections from prefabricated concrete elements, which shall take away the stormwater into open reservoir, shall be constructed. The additional construction of deep drainage is specific for the trench-type repository. It collects the stormwater penetrated through the surface of the slope – water is collected by drainage pipes under the south edge of the loess-cement cushion and is taken away into the stormwater network.

During the process of construction of the trench-type repository, an additional area in the amount of 0.40 hectare should be necessary to be used for temporary storage of 68 000 m^3 of humus which shall be used after the construction of stage 1 at Radiana site and 90 000 m^3 of humus which shall be used to build the loess-cement cushion. A site at the distance of 2 km is identified; negotiations with the owner[23] have been opened.

2.2.1.5 PASSIVE SYSTEMS TO ENSURE THE SAFETY

The passive system to ensure safety is represented by the elements of the multi-barrier system. The following elements are considered as elements of the multi-barrier system, according the authors of the paper:

- **First engineering barrier** is the form of waste, which is cemented radioactive waste, some of which has already been put in steel drums with or without super pressure. The safety function of the form of waste (cemented matrix in which the waste is included) is connected with entry of radionuclides in the hard phase of the matrix as well as their detention by adsorption and precipitation in a highly alkaline environment of the cement. The cemented matrix is considered as chemical barrier which does not lose its safety functions for thousands of years.
- **Second engineering barrier** is a reinforced concrete container with thick walls, a bottom plate and a lid, where the cemented radioactive waste is put, with the free space between the cement matrix of the waste and the lid of the concrete container being filled with grout, forming a monolithic block. The reinforced concrete container should allow the waste to be extracted before the final closure of the NDF. The safety function is to ensure complete retention by maintaining mechanical integrity, incl. integrity of the clamps, for the period of operation of the repository, which shall be about 60 years. The reinforced concrete container maintains its functions of a chemical barrier for thousands of years.

[21] Ordinance on provision of physical protection of nuclear facilities, nuclear material and radioactive substances, SG No 77/3.09.2004, last amended. SG No 44/9.05.2008

[22] Ordinance № 7/08.06.1998 on systems for physical protection at construction sites, SG No 70 / 19.06.1998

[23] Geoconsult OOD, Research on the location of a landfill for surplus soil and temporary landfills for humus and loess, 2014

- **Third engineering barrier** of the repository includes the disposal cells which are made of reinforced concrete, foundations, closing slabs and filling material. The specified safety function is retention of the potentially released radionuclides from packages with RAW by maintaining the integrity of the cells during the operation of the repository which lasts 60 years, the closure of the repository which lasts 15 years and entire period of institutional control which lasts 300 years. As it is said further above, the design lifetime of the structures of the repository is 375 years. The concrete preserves its functions of chemical barrier for thousands of years.

- **Fourth engineering barrier** includes external loess-cement base and multilayer coating. Besides being a barrier to migration of radionuclides, the base also increases the thickness of the unsaturated zone and improves the overall condition of the base. A multilayer protective coating shall be made of natural materials (clay, sand, gravel, etc.) and has a structure to ensure a number of important safety functions and the following ones are the most important:
  - → To minimize to maximum extent the infiltration flow of stormwater through the repository system guaranteeing infiltration hydraulic flow below 1.5 L/m^3 a year through the repository modules.
  - → To serve as a barrier against external distortion of the system of barriers from people, animals or plants;
  - → To ensure protection against continuous agents of erosion, such as rain and wind.
- **Fifth (natural) barrier** is performed by the favourable characteristics of the site.

2.2.1.6 ACTIVE SYSTEMS TO ENSURE THE SAFETY

There are no active systems to ensure the safety. The structure of the trench-type repository is such that active systems to ensure safety are not necessary.

2.2.1.7 DESCRIPTION OF THE PROCESS OF DISPOSAL OF RCC IN A TRENCH-TYPE REPOSITORY

Activities related to the management of radioactive waste which are common for two technologies for burial of radioactive waste are specified in chapter 1. Specific activities which are determined by the technology for burial in a trench-type repository are described in this part.

A detailed control of the cell incl. control on waterproofing is performed before the start of disposal of RCC in specific disposal cell. The sliding roof, in which the overhead crane is disposed, is positioned over the cell and the drainage of the cell is connected to the network for control of infiltrated water. The sliding roof encompasses not only the cell in which the radioactive waste is disposed but the unloading area located on the external side of the rows of cells thus preventing external atmospheric conditions on the process of unloading. **Figure 2.2-6**.

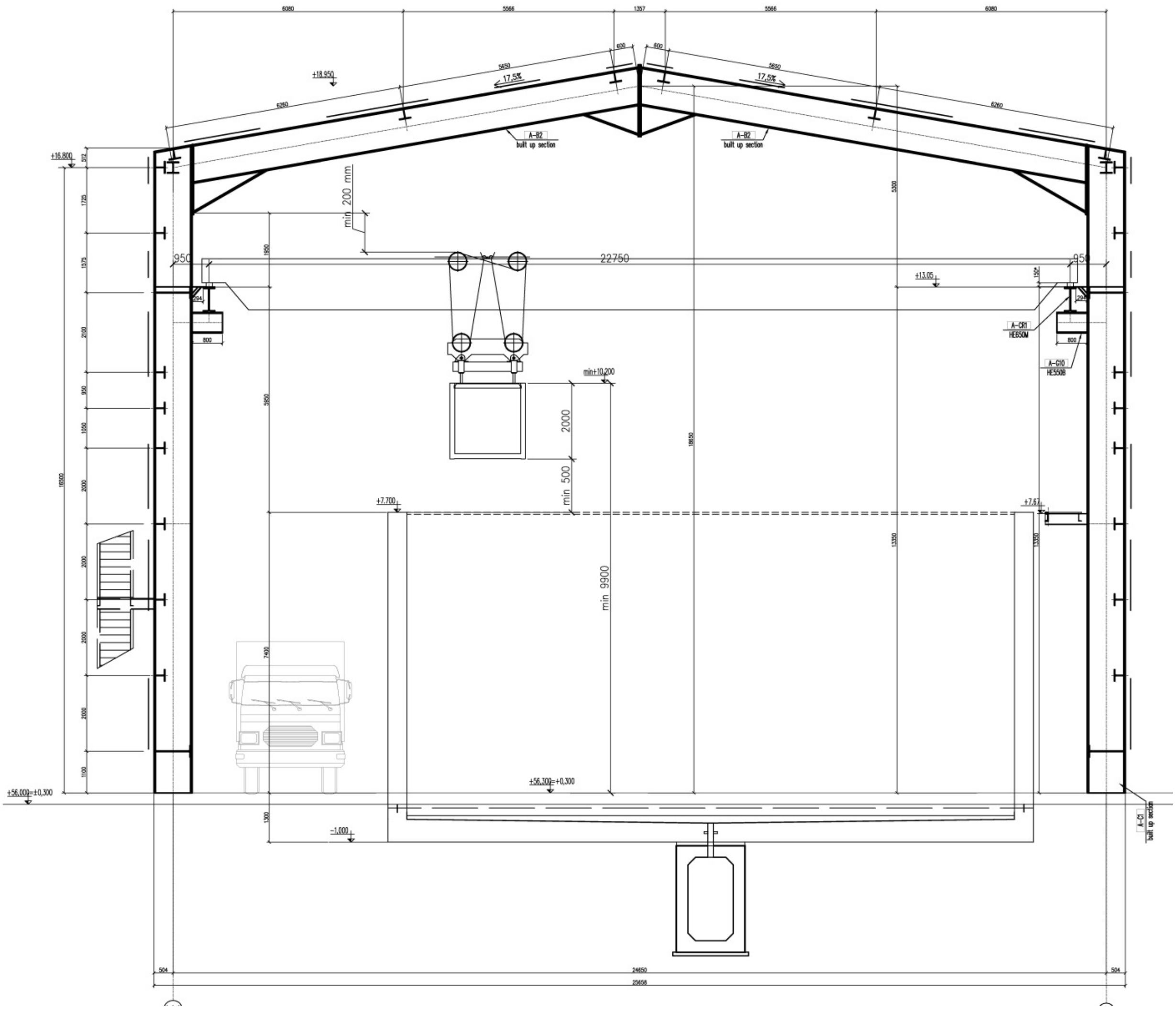

FIGURE 2.2-6 SCHEME OF THE SLIDING WAREHOUSE WITH AN OVERHEAD CRANE SITUATED ON THE DISPOSAL CELL AND UNLOADING AREA

The radioactive waste enters into the area of the cell, which shall be filled in, by specific route from the buffer storage. The transportation shall be performed by means of special internal transport vehicle. The project envisages the use of such special transport vehicle which allows the participation of the personnel in loading and unloading operations to be reduced to minimum. It is envisaged the use of a tow truck equipped with transport platform where reinforced concrete container could be placed on. The transport platform is loaded with RCC in the buffer storage by means of an overhead crane which has a remote control system. After the arrival of the cell in the unloading area, the transport platform is detached remotely from the tow truck which leaves the area and from this moment the operation related to the disposal of RCC is controlled remotely by means of the remote control of the overhead crane situated on the sliding roof which is controlled by the main control room by a video surveillance system. The package of radioactive waste is attached to the gripping device of the crane, unloaded on the platform, positioned over the predetermined place for disposal in the cell and it is descended to its final location. The packages of radioactive waste are placed on 4 rows in 72 positions in the cell. The scheme of disposal is presented in **Figure 2.2-7** and it is the same for each row of RCC in the disposal cells. It is determined strictly in view of optimization of the stress distribution inside the disposal cell. The structure of the cells ensures tolerance of 0.45 m. in length and 0.2 m. in width in tight stacking of RCC. In this way a T-shaped joint is formed which is filled with gravel later.

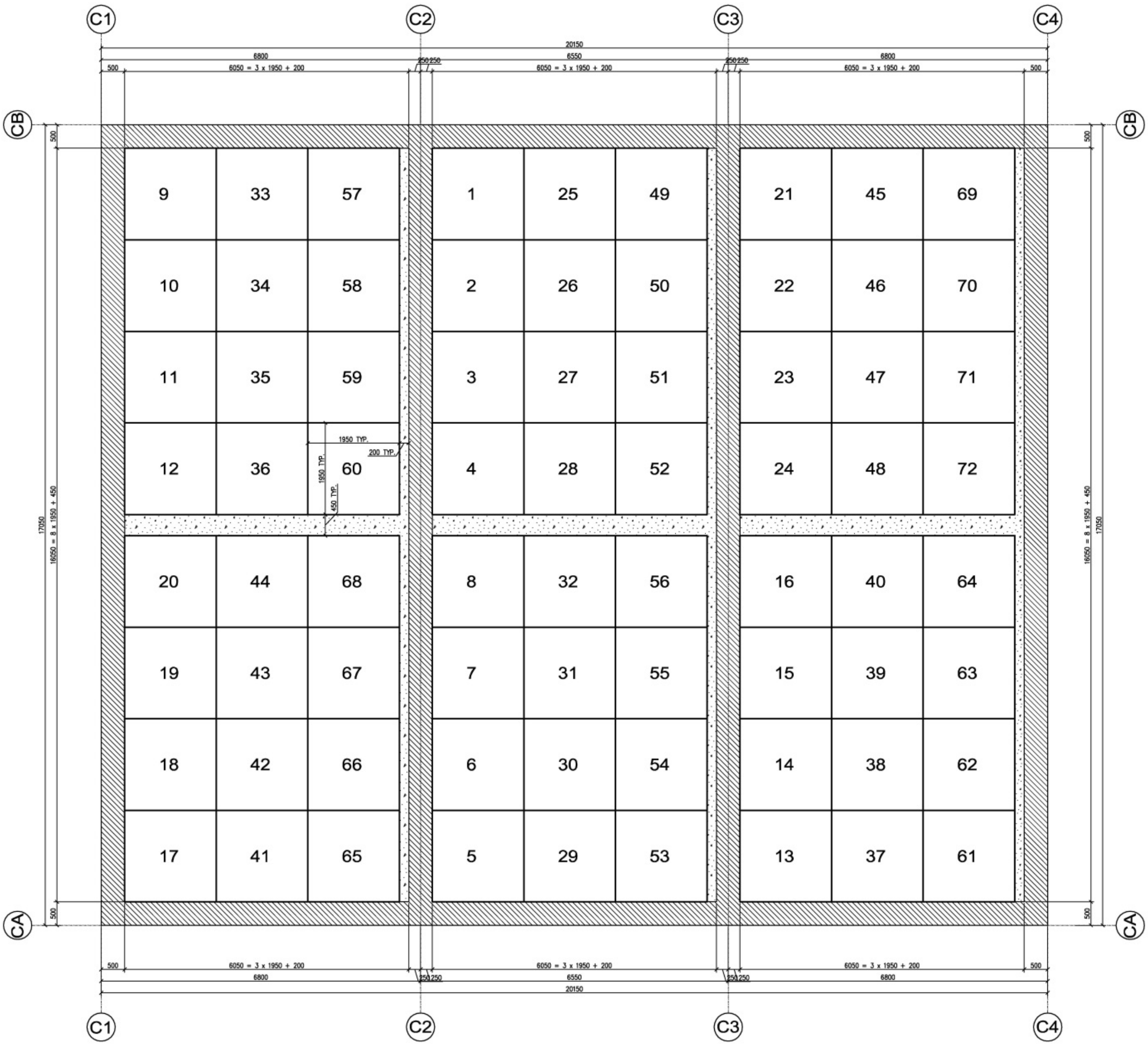

FIGURE 2.2-7 SCHEME OF DISPOSAL OF RCC IN A DISPOSAL CELL

The scheme of filling in combination with the buffer storage allows optimization of the disposal of RCC for purposes of radiation protection and safety by disposing the packages having relatively higher activity on the lowest row.

The scheme of filling of cells from specific platform optimized in respect of the process of disposal of the loads and lifetime is presented in **Figure 2.2-8**. The disposal of RCC starts from the first cell of row A of the platform. After its filling, the filling of first cell in row B starts as the covering of the cell in row A with roof panels and construction of a new slab is done simultaneously with the filling of the cell in row B.

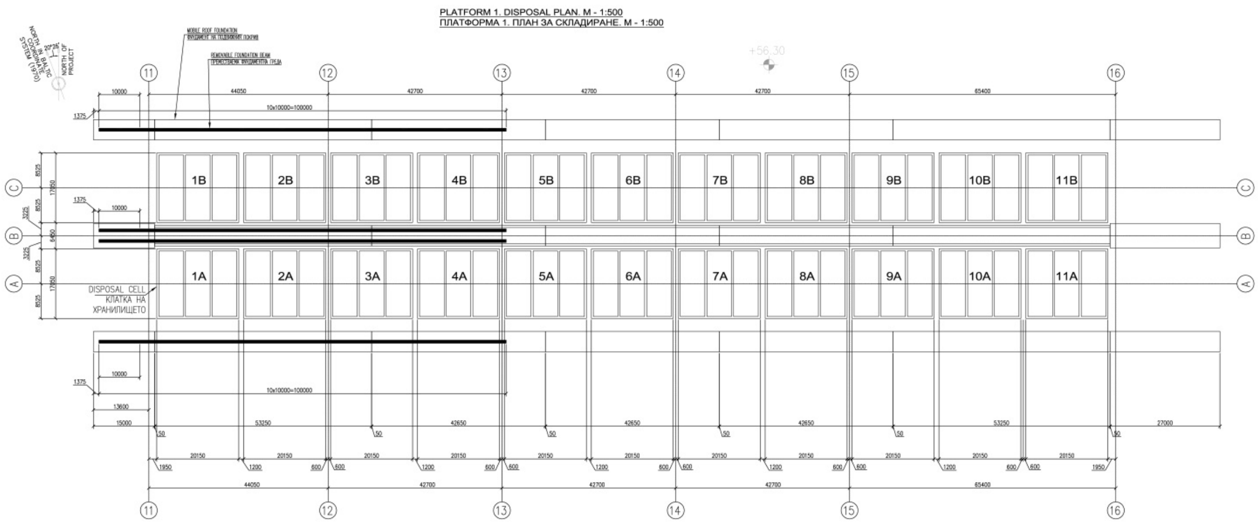

FIGURE 2.2-8 SCHEME OF THE FILLING OF CELLS FROM A SPECIFIC PLATFORM

2.2.1.8 *INFILTRATION CONTROL SYSTEM*

The infiltration control system is designed to catch and collect separately the infiltration from each internal chamber of the disposal cells. It is a system of pipelines located in underground gallery accessible to people which is placed under each row of cells. The galleries are built of loess-cement cushion and their structure is presented in **Figure 2.2-9**.

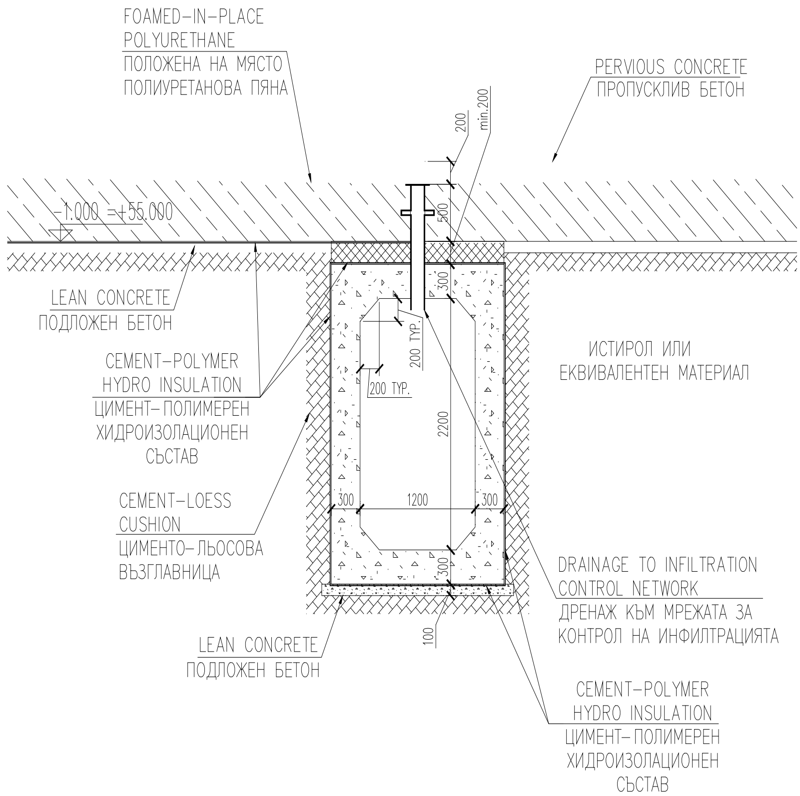

FIGURE 2.2-9 CROSS SECTION OF THE GALLERIES OF THE INFILTRATION CONTROL NETWORK

The galleries are constructed of reinforced concrete – 0.30 m. thickness of the walls, foundations and the roof slab. The waterproofing is made of cement-polymer hydro insulation (waterproofing material). Internal dimensions of the galleries are 1.20 m. width and 2.20 m height and they are sufficient for the disposal of the system of pipelines, control equipment and free passage of inspection personnel. The galleries are designed in segments – 42.70 m. long. Universal compensatory connections of stainless steel which take the extensions are installed in the joints with length of 0.1 m. between the segments. The galleries are constructively independent of the cells of the repository and they are separated by a layer of polystyrene - 0.20 m. thick which is sufficient to take the maximum subsidence of the cells of the repository. There are transverse galleries at the ends of each platform of the disposal cells which serve as access points to two longitudinal galleries which pass under the rows of cells in each platform. Thus, each gallery has two independent entrances. The scheme of the disposal cells with galleries of the infiltration control network is presented in **Figure 2.2-10**.

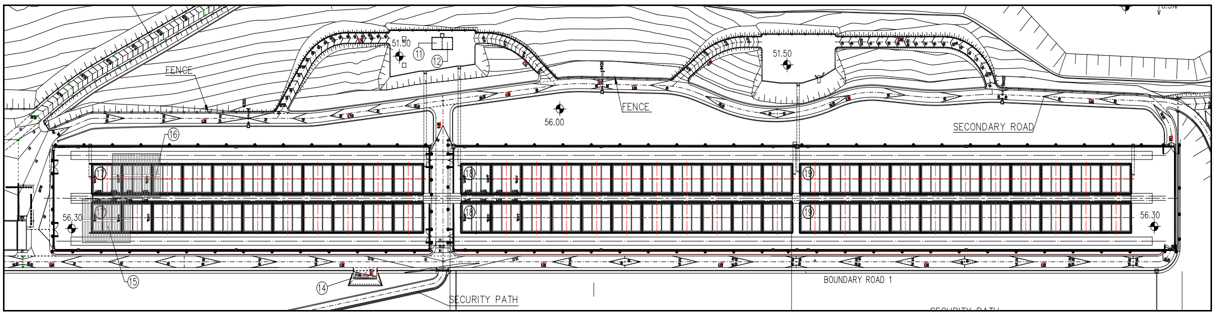

FIGURE 2.2-10 LAYOUT OF THE PLATFORMS OF THE SITE WITH GALLERIES OF THE INFILTRATION CONTROL NETWORK

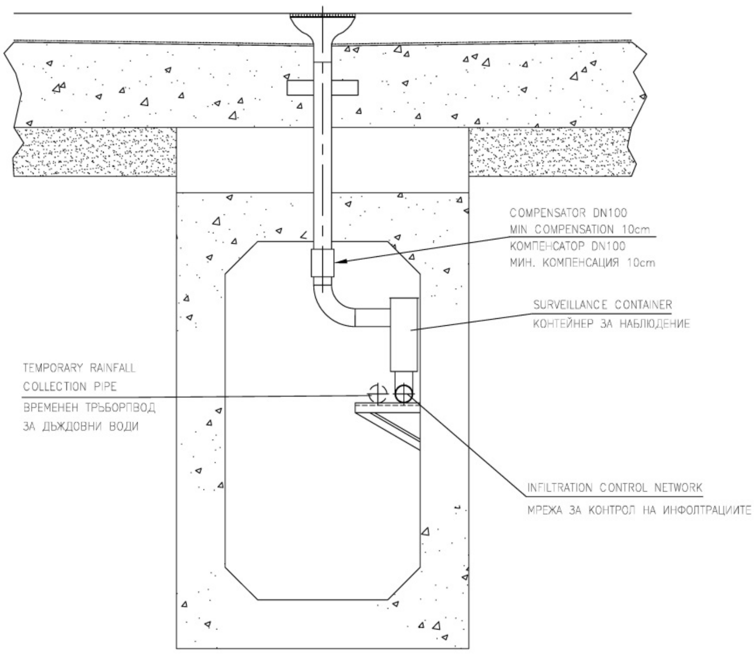

FIGURE 2.2-11 INFILTRATION CONTROL NETWORK DURING THE OPERATION AND AFTER CLOSURE

As it is specified further above, each cell of the repository is separated by internal separation walls into three sectors and 96 containers of radioactive waste are disposed in each of them. The bottom of each sector has a slight gradient to the central part which allows water to be taken away to the central pipe connected with a pipeline equipped with a sampler. The sampler is 10-litre container for surveillance, made of transparent PVC equipped with a sampling point which are presented in **Figure 2.2-11** and **Figure 2.2-12**.

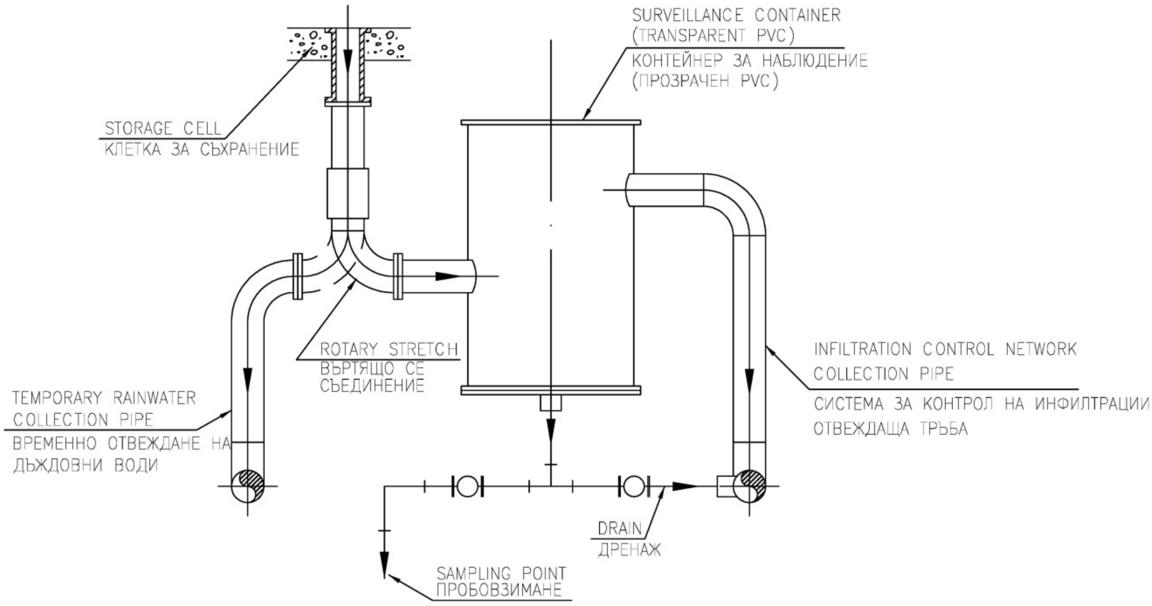

FIGURE 2.2-12 INFILTRATION CONTROL NETWORK– MODEL SCHEME OF CONNECTION

The pipes are made of PVC with 110 m. diameter. The gradient of the pipes is 0.005 to the collecting reservoir which allows gravity outflow of the collected water. Two receiving reservoirs are provided. The water from the empty cells is collected in one of them and in the other – the water from the cells where radioactive waste is disposed. The receiving reservoir is designed to take the maximum quantity of infiltrated water within a year. The infiltrated water is considered as potentially contaminated and is controlled due to the presence of radiation pollution. As it is specified in chapter 1 of the present REIA, the processing of radioactive waste in NDF is not envisaged. In case of presence of radiation pollution, water shall be transported to SU RAW-Kozloduy for processing. Pure water is taken away in storm water reservoir.

The infiltration control system designed allows not only the control of individual cells of the repository but the sectors of the cells.

The infiltration control system is designed for the entire lifetime of the repository – during the operation and institutional control which allows a strict control on the condition of the repository during the institutional control. The design lifetime of the gallery is 375 years. The laying of pipeline system in the drainage gallery allows the implementation of control and respective maintenance.

2.2.1.9 CONTROL AND MONITORING METHODS DURING THE OPERATION OF NDF

According to the authors of this paper the following activities shall be implemented during the operation of the repository:

(1) radiation monitoring of the site and surveillance area which does not depend on the type of the repository (tunnel-type or trench-type) and it is specified in chapter 1 of the present REIA;

(2) hydrological monitoring – it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

(3) seismic monitoring – it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

(4) meteorological monitoring on the site - it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

The design of the trench-type repository allows the implementation of direct control and monitoring over the condition of the disposed waste and structures of the trench repository. The following control shall be implemented during the operation:

2.2.1.9.1 GEODETIC CONTROL

A control shall be implemented over the horizontal and vertical deformations precise geodetic measurements both ground base and structures. Having in mind that the Radiana site is very close to Kozloduy NPP, the site is included in the network for geodetic monitoring of the plant which has been developed and integrated in 1998. Since 1998 five campaigns related to surveillance within the area of NPP for measurement and assessment on local geodynamics have been made. The studies show that geodynamic situation in the area is calm with insignificant horizontal and vertical displacements. SE RAW has been constructed additionally a local network for preoperational geodetic monitoring on the site[24,25] which is synchronized with the network for geodetic monitoring of the NPP. The local network of Radiana site consists of (1) a reference system of deep stable elevation benchmarks (two groups by three benchmarks) situated in areas having stable ground base and they shall not be affected by the construction activities during the construction of NDF; (2) working geodetic network of 26 survey markers together with devices for forced centring and elevation benchmarks for monitoring situated along the north and south border of the site. The structure of the deep elevation benchmarks and survey markers is presented in **Appendix 8-II.2**. In **Figure 2.2-13** is presented a survey marker and elevation benchmark bolt.

[24] Preoperational geodetic monitoring of Radiana site a report on task 1 Planning and Design of the spatial network for geodetic monitoring, 2014.

[25] Preoperational geodetic monitoring of Radiana site a report on task 2 Construction at stage 1 of the spatial geodetic network for geodetic monitoring – before the start work on the construction of NDF, 2014

(a) an elevation benchmark bolt is installed on a survey marker *(b)elevation benchmark bolt*

FIGURE 2.2-13 ELEMENTS OF THE NETWORK FOR GEODETIC MONITORING OF THE GROUND BASE

A precise geodetic control on the structure of the cells shall be performed during the operation of the repository in compliance with the Instruction on examination of the deformations on buildings and facilities by geodetic methods[26]

The design envisages the use of combined benchmarks which are presented in **Figure 2.2-14** which provide a possibility to be surveyed spatial (horizontal and vertical) displacements of the building structure of the cells and they shall be installed at a height of about 40 cm from the base of the external wall of the cells. The control shall be performed in compliance with the above-mentioned instruction [27]before, during and after the filling of cells until the deformation processes stop determined by the subsidence of the filled cells and after that it shall be performed periodically.

The elevation network for geodetic control on the structure of the cells is specified in **Appendix 8-II.3**

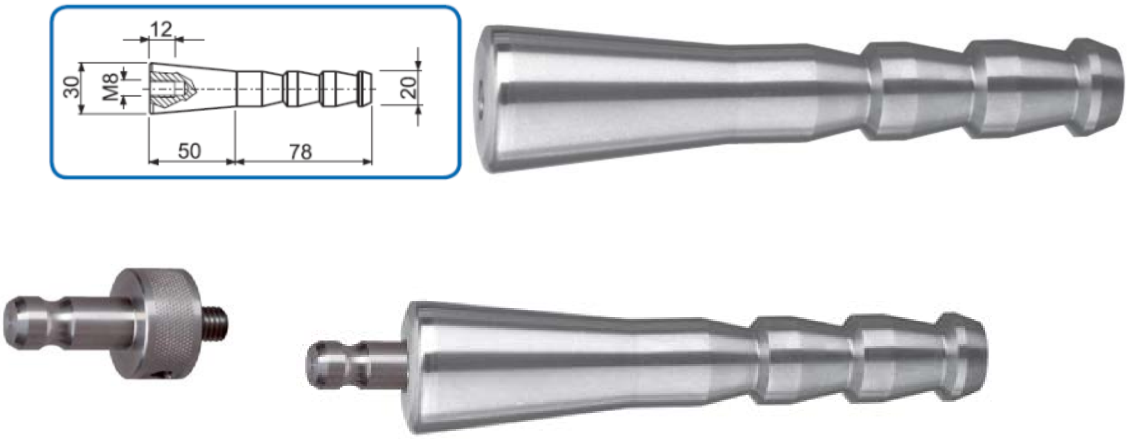

FIGURE 2.2-14 PARTS OF A COMBINED MARK FOR ASSEMBLY IN THE BUILDING STRUCTURE OF THE CELLS

[26] Instruction on examination of the deformations on buildings and facilities by geodetic methods

[27] Instruction on examination of the deformations on buildings and facilities by geodetic methods

2.2.1.9.2 *RADIATION CONTROL*

The radiation control for the purposed of radiation protection is specified in chapter 1. Only the specifics determined by the structure of the repository are specified here.

The structure of the repository is such that allows the disposal of stationary devices for radiation control of the power of the equivalent dose gamma radiation of the cells in the repository. The additional stationary dose meters, connected by continuous mode with the radiation control system, are mounted under the sliding roof to control continuously the processes of filling up the cells and its closure with roof panels.

2.2.1.9.3 *CONTROL OVER THE CONDITION OF THE PACKAGES AND ENGINEERING BARRIERS OF THE REPOSITORY*

The input control of the reinforced concrete containers which enter into the NDF for burial is specified in chapter 1. In this chapter the control determined by the specifics of the technology for burial – a trench-type repository is described.

The structure of the repository is such that allows permanent and full control over the condition of the buried RCC and engineering barriers of the repository. It is carried out by means of the above-mentioned infiltration control network which allows at any time to be determined the condition of the packages during the filling of the cells and afterwards as well as the condition of the structure incl. the roof panels and slabs.

2.2.1.10 *EXTRACTION OF RCC DURING OPERATION*

Pursuant to the requirements of the nuclear legislation[28], the design of the repository for burial of radioactive waste should provide a possibility for extraction of the packages with radioactive waste during the operation of the repository. This includes two aspects:

(1) A possibility to extract the entire quantity of waste in the facility;

(2) A possibility to extract the future defective package/packages.

The design of the trench-type repository allows easy implementation of the extraction of the packages with radioactive waste in both aspects by means of basic equipment for handling and transport which is used for disposal of RCC in the cells of the repository.

The possibility to extract the future defective package/packages is facilitated taking into account the fact that the construction of the repository is such that the infiltration control system locates the exact sector of the defective package. In the most pessimistic case to reach the defective package, located in the lowest row, it is necessary to be removed no more than 96 RCC. The small number of packages and use of remotely controlled overhead crane guarantee minimum dose load on the operational personnel.

Although the nuclear legislation, safety standards of the International Atomic Energy Agency and good practices in developed European countries do not require an option to extract the radioactive waste in the period after the closure of the repository, the structure of the repository allows this to be carried out by standard devices for excavation and loading and unloading works.

2.2.1.11 *NEED OF TEST FACILITIES BEFORE THE CONSTRUCTION OF THE TRENCH-TYPE REPOSITORY*

The construction of the trench-type repository is carried out by standard construction means of the conventional construction and there is no need of special test facilities before the construction.

Of course, the recipes for loess-cement and concrete with concrete materials shall be sampled in accordance with good building practice.

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[28]. Ordinance on safe management of radioactive waste SG No 76/30.08.2013

2.2.1.12 CONSTRUCTION OF A TRENCH-TYPE REPOSITORY

The construction of a trench-type repository shall be executed by use of standard construction machines in strict compliance with the requirements for quality of materials and quality of execution as it complies with the requirements to build a facility for radioactive waste management. The standard construction equipment which shall be used is specified in **Appendix 8-II.4.** As it is said further above, the construction shall be executed in stages. The first platform with 22 cells for burial of radioactive waste, infrastructure on the site and service buildings and facilities shall be built in the first stage. The construction of the second and third stage (respectively the second and third platform with 22 cells for burial each) shall be carried out by physical separation of the construction activities related to the operation by means of fence/fences and use of separate access road for the machines, materials and builders so that any impact could be excluded.

The organisation of the construction includes the following main activities:

(1) Preparation of the site: cleaning the site of the existing vegetation incl. stumps and roots, removal of near-surface layer, which is rich in humus and placing it on a temporary platform in accordance with the requirements for its conservation[29]; construction of construction roads at the site, preparation activities for construction of the landfill for earth masses which shall be used during the closure of the repository; preparation activities for construction of surface water reservoir;

(2) Excavation works. During excavation of the loess layer, the collapsible loess from the upper layers shall be stored at a temporary landfill close to Radiana site. According to the geological report[30] and on the basis of the experience from the construction of the loess-cement cushion during the construction of Kozloduy NPP, the composition of the loess from the upper layers is more suitable for implementation of loess-cement. The loess that shall be used during the closure of the repository shall be disposed at the landfill prepared for earth masses. The loess from lower layers of the excavation (last 6 m.) has more clay in it and it is unsuitable to be used during the closure of the repository. It is considered as surplus soil and it shall be transported outside the site;

(3) Execution of the loess-cement cushion which is 5.00 m. thick and 57.10 m. wide. It shall be executed in layers – 25 cm thick with cement content varying from 2 to 8%. Drainage galleries under each row of cells for burial are constructed in the loess-cement cushion and foundations of the sliding roofs are placed.

(4) Construction of reinforced concrete cells starting from the bottom slab – 60 cm thick, the walls of the cells and internal walls – 50 cm thick and finishing by covering the ready cells with reinforced concrete roof panels which are placed on the walls of the cells by means of a crane and they protect them until their commissioning; lying waterproofing. Continuity of the process is monitored strictly during the construction of the reinforced concrete structures. An additional finish layer of the loess-cement cushion is constructed up to the height that covers the bottom slab of the cells.

(5) Construction of sliding roofs and overhead cranes with load capacity of 40 tons incl. installation of railroad along which the sliding roofs move;

(6) Construction of drainage systems incl. drainage system under the slope and drainage systems for surface water around the cells;

[29] Ordinance № 26 for land reclamation, improvement of poor lands, removal and utilization of the humus layer SG No 89/ 22 .10 1996, amended. SG No30 /22 .03 2002

[30] Report on the results of geological, geophysical, engineering and geological, hydrogeological and hydrological laboratory studies held,2010; Geotechnica ABV

(7) Construction of auxiliary buildings and facilities incl. the building of the buffer storage for radioactive waste before its burial shall be carried out simultaneously with the construction of the cells of the repository;

(8) Covering with soil and landscaping.

2.2.1.13 EARTH MASSES AND HUMUS MANAGEMENT

According to the authors of the design, 68 000 m^3 humus shall be obtained which shall be used again to cultivate the environment during the first stage of construction of a trench-type repository together with facilities and infrastructure at the site. During the construction this humus shall be stored at a temporary site, located at a distance of around 1 km. from Radiana site [31] in complete compliance with Ordinance № 26 on reclamation of disturbed areas, improvement of low productive lands, removal and utilization of the humus layer[32]. The humus, which shall be removed during the second and third stage of construction of the repository in the amount of 19 000 and 24 000 m^3 respectively, shall be used again to reclaim the environment and improve low productive lands according to the will of population within the area.

A significant part of excavated earth mass during the first stage of construction of the repository shall be stored at a landfill located at the Radiana site and specified further above because it shall be used for backfilling and construction of protective multi-barrier coating during the closure of the repository. Negotiations have been opened with the owners regarding the disposal of surplus soil which is not suitable for the purposes of the closure of the repository in the amount of 220 000 m^3 on places identified in the research[33].

The surplus soil, which shall be obtained during the second and third stage of construction of the repository, shall be used for reclamation of the disturbed areas.

A landfill for earth masses with a capacity of 625 000 m^3 shall be constructed at the site. The disposal of the landfill is presented in **Figure 2.2-15** and the cross section – in **Figure 2.2-16**.

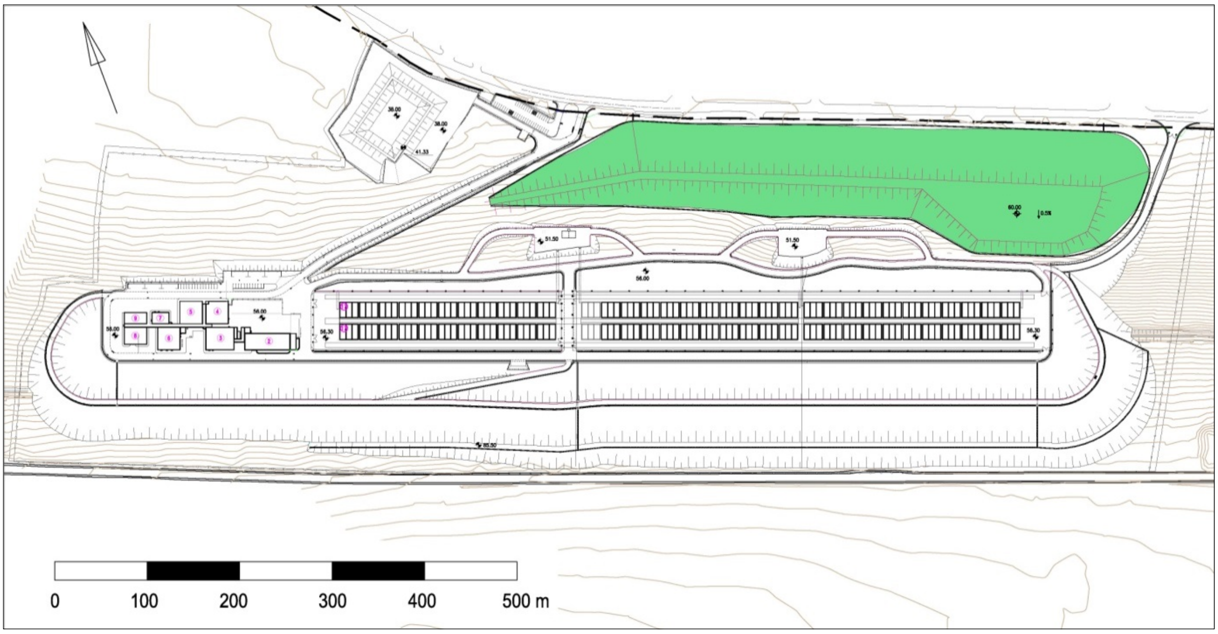


FIGURE 2.2-15 DISPOSAL OF A LANDFILL FOR EARTH MASSES

[31] Geoconsult OOD, 2014 Research on the location of a landfill for surplus soil and temporary landfills for humus and loess;

[32] Ordinance № 26 on reclamation of disturbed areas, improvement of low productive lands, removal and utilization of the humus layer, prom. SG No 89 /22.10.1996, amend. and suppl. SG No 30/2002);

[33] Geoconsult OOD, 2014 Research on the location of a landfill for surplus soil and temporary landfills for humus and loess;

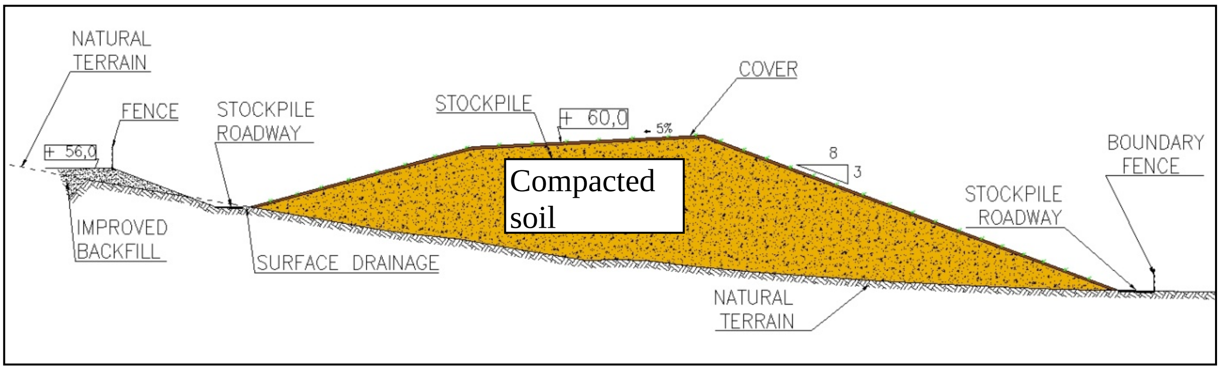


FIGURE 2.2-16 DESIGN OF THE LANDFILL FOR EARTH MASSES – CROSS SECTION

The landfill has an area of 70 000 m², the maximum elevation is +60 m. The ground base under the landfill has a gradient of 8:3 and the slope has a gradient of 8:3. The earth mass is compacted by standard methods (bulldozer). A humus layer is placed on the landfill grass is planted on it which shall be fertilized and watered. The sustainability of the gradient is proved by numerical methods and experimental observations.

2.2.1.14 STAGES IN CONSTRUCTION OF A TRENCH-TYPE NDF

According to the authors of the design, the trench-type repository shall be constructed in three stages:

- → Stage 1 includes construction of the first platform with 22 cells for burial of radioactive waste, auxiliary buildings and facilities and infrastructure at the site, the capacity in the first stage is 6336 RCC;
- → Stage 2 includes the operation of the first platform built and construction of the second platform with 22 for burial of radioactive waste; the total capacity in the second stage is 12 672 RCC;
- → Stage 3 includes construction of last platform with 22 disposal cells simultaneously with the operation of the second platform; the total capacity of the repository is 19 008 RCC.

During the second and third stage, the construction of the platforms for burial of radioactive waste shall be performed only thorough a road in the eastern end of Radiana site as the part of the repository which is in operation is physically separated from the construction section by fences. The scheme regarding the construction of new platforms during the operation of the repository is presented in **Appendix 8-II.5.** Thus, a physical separation has been ensured, activities or materials cannot be mixed. The distance ensured between the cells, which are in operation, and the construction site guarantees the lack of radiological impacts on the construction workers. The scheme of construction stages is presented in **Figure 2.2-17**.

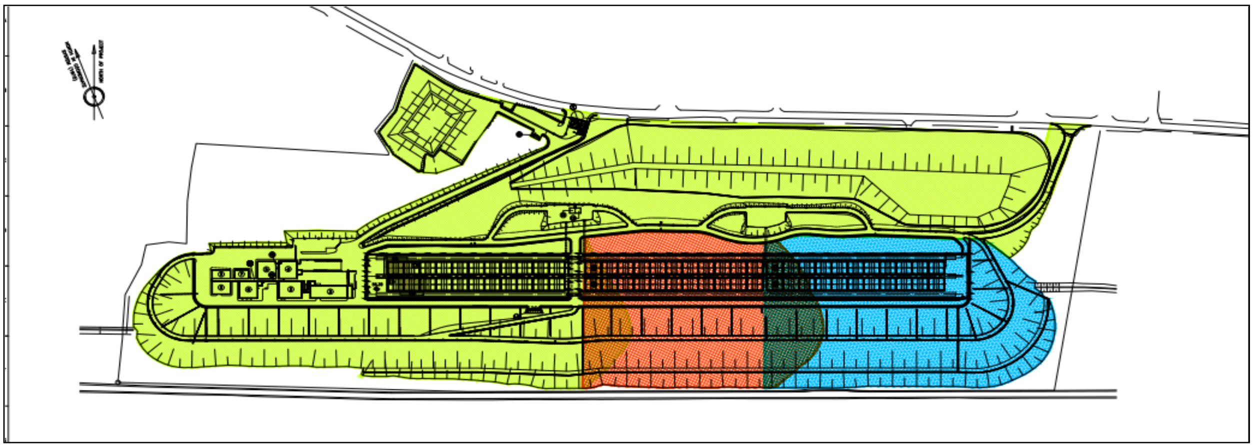


FIGURE 2.2-17 CONSTRUCTION OF INDIVIDUAL STAGES OF A TRENCH –TYPE REPOSITORY

2.2.1.15 NEED OF TEST FACILITIES BEFORE THE CLOSURE OF A TRENCH-TYPE REPOSITORY

During the operation of the repository, the protective multi-barrier coating shall be tested at a specially constructed test site.

2.2.1.16 CLOSURE OF A TRENCH-TYPE REPOSITORY

In compliance with the requirement of the nuclear legislation[34,35] the closure of a repository for burial of radioactive waste shall be carried out pursuant to the technical design for closure, closure plan, safety assessment in post operational period and safety assessment before closure which are approved by Nuclear Regulatory Agency. The closure of the repository after the end of operation is subject to individual environmental impact assessment. The process of closure of the NDF and requirements to it are specified in detail in chapter 1. The specific characteristics of the closure of the trench-type repository are specified in the present part.

According to the authors of the paper, the closure of the cells of the repository includes filling the minimum free space left with gravel, lying roof panels, construction of roof slab and its waterproofing. This shall be executed as follows:

(1) Stoking gravel to fill the gaps between the packages of RAW in order to prevent movement of the packages. This gravel is delivered by a truck to the unloading area. The gravel from a device for scooping gravel is poured through the hose through a special device adapted for an overhead crane. The filling continues until gravel reaches the top of the last row of the packages.

(2) Prefabricated concrete panels are placed on the top of the walls of the cells by means of a remote control situated in the main control room. It is carried out by means of an overhead crane located under the sliding roof and video surveillance system. These panels protect the workers during the implementation of the activities related to the construction of the closing slab;

(3) Placing a layer of polyethylene on the concrete panels to prevent the connection of new concrete of the roof slab and roof panels and ensure waterproofing which prevents the penetration of concrete into the joints of the panels;

(4) Pouring of concrete levelling layer;

[34] Ordinance on safe management of radioactive waste SG No 76/30.08.2013

[35] Ordinance on the procedure and issuance of licenses and permits for safe use of nuclear energy, prom. SG No 41/18.05.2004, last amend. SG No 76/76/5.10.2012

(5) Building a closing reinforced concrete slab 0.6 m. thick as follows: (a) assembly and closure of reinforcement steel bars; (b) laying shuttering and pouring concrete; (c) removal of shuttering;

(6) The roof slab is water-resistant after the lying of waterproof coating.

The above-mentioned operations are carried out under the sliding roof which ensures protection from atmospheric conditions of the packages and works related to the closure. The overhead crane is also located under the sliding roof which is used for lying the packages of RAW on their place in the cells of the repository and which is used in the operations related to the closure of the cells. According to the authors of the design, the closure of one cell continues within 4 -5 months.

After the end of operation period of the repository follows its final closure. The final closure of a trench-type repository is based on the construction of protective multi-barrier coating which guarantees infiltration hydraulic flow significantly lower than that one in the natural environment thus minimizing the access of moisture to the repository system. The protective multi-barrier coating consists of:

(1) one or several resistant barriers based on the weak penetrating material such as a compacted clay which are designed to reduce the entry of water into the disposal cells;

(2) One or several conductive barriers which use the capillary barrier phenomena to take the water away from the waste. The barrier should be consisted of strongly conductive material such as coarse gravel lying in the base of fine material, a conductive layer. Due to the differences in the unsaturated hydraulic conductivity between two layers (perfectly a rate around 1000), breaking of the capillaries on the surface of two layers occurs. The water is taken away sidewise in soil with fine texture above the surface of the layer when it is with negative capillary pressure.

The protective multi-barrier coating proposed by the authors of the design is presented in **Figure 2.2-18**.

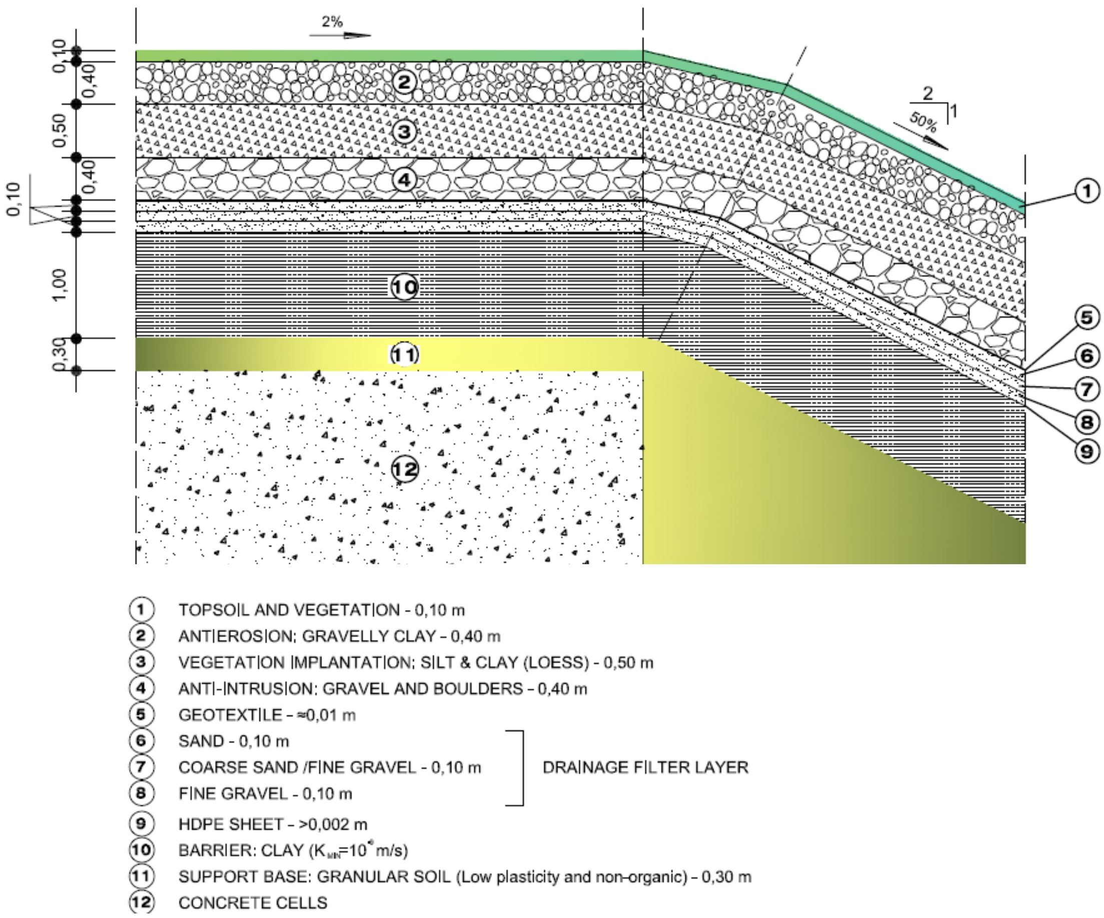


FIGURE 2.2-18 PROTECTIVE MULTI-BARRIER COATING OF A TRENCH-TYPE REPOSITORY

The protective multi-barrier coating consists of the following layers which are presented in the figure:

(1) Humus upper layer on which vegetation with shallow roots – grass shall be planted. The thickness of the layer is 10 cm., the hydraulic conductivity of the layer is 10^{-2} m/s;

(2) Anti-erosion layer of clay with gravel whose thickness is 40 cm. and hydraulic conductivity of the layer - 10^{-2} m/s, which shall build the layers;

(3) Base of compacted loess – 50 cm thick and hydraulic conductivity 10^{-7} m/s which shall built the layer;

(4) Protective layer of gravel and rocks – 40 cm. thick and hydraulic conductivity 10^{-1} m/s whose function, except to protect from mechanical damage, shall be to take the penetrated water away into the drainage system;

(5) Geotextile, 1 cm. thick and hydraulic conductivity$10^{-4}÷10^{-3}$ m/s whose function shall be to separate two layers physically – upper and lower drainage layers;

Main drainage layer which shall drain the moisture that shall get to it and it shall take it away into the drainage system. It shall consist of the following three layers, each of them 10 cm. thick:

(6) A layer of sand with hydraulic conductivity 10^{-3} m/s;

(7) A layer of coarse sand and fine gravel with hydraulic conductivity 10^{-2}m/s;

(8) A layer of fine gravel with hydraulic conductivity 10^{-1} m/s;

(9) A waterproof layer of high density polyethylene sheets or Bentonite geocomposites with 0.2 cm thickness and hydraulic conductivity of 10^{-11} m/s, which shall divide the upper primary drainage filter layer from the bottom compacted layer of clay;

(10) Basic aquitard of watertight clay - 100 cm thick and hydraulic conductivity 10^{-9} m/s;

(11) A supporting base of low plastic materials - 30 cm. thick and hydraulic conductivity 10^{-5} m/s. The base includes sand and clay and fine gravel.

(12) A concrete cell with hydraulic conductivity 10^{-8} m/s;

The above-mentioned drainage layers take the infiltrated water into drainage ditches located along the north border of the site which are subject to monitoring and control.

The so-designed multilayer protective cover provides infiltration hydraulic flow under 1.5 L/m^2 per year in the repository modules. This value has been proven by long measurements of infiltration flow in experimental multilayer protective coatings with identical structure in the Centre d'Obe- France and El Cabril - Spain.

Apart from the protective multi-barrier coating during the closure of the repository, a drainage system is constructed close to the base of the southern slope of the terrain which drains the water from the slope and does not allow it to get to the aquitard of watertight clay. It is a drainage channel which is filled with clean gravel and coating of appropriate materials to preserve its integrity.

The loess which is stored at the site in the landfill for earth masses is used for backfilling to rehabilitate the original condition of the site.

The layout of closed repository is presented in **Figure 2.2-19**.

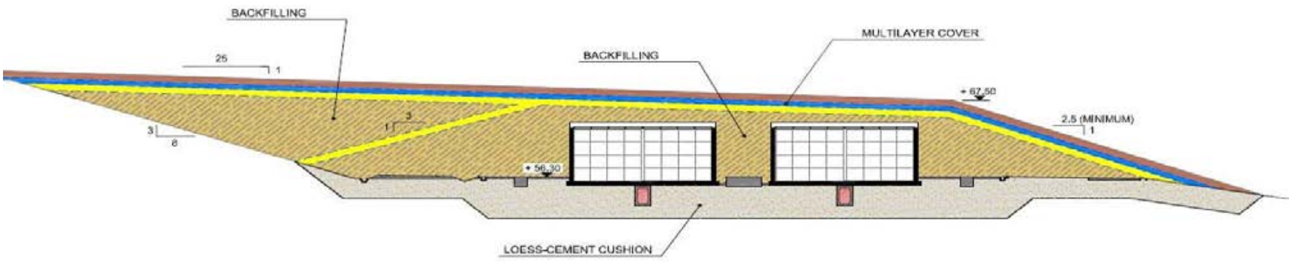


FIGURE 2.2-19 CROSS SECTION OF A CLOSED TRENCH-TYPE REPOSITORY

A revision on the infiltration control system including the galleries which is designed to operate 375 years is carried out simultaneously with the implementation of the above-mentioned activities related to the construction of the multi-barrier protective coating and backfilling.

Thus, safe isolation of the radioactive waste from people and environment is ensured after the closure of the trench-type repository. The stormwater is taken away by the protective multi-barrier coating. A very small part of it can be infiltrated through the protective coating. A full control over the repository is ensured. If a minimum quantity of moisture gets to the repository, it shall be caught by the infiltration control system.

2.2.1.17 METHODS RELATED TO CONTROL AND MONITORING DURING THE PERIOD OF INSTITUTIONAL CONTROL

The activities during the institutional control which are the same for two types of repositories (tunnel-type and trench-type) are specified in chapter 1 of the present REIA.

The project envisages full control on the condition of the buried radioactive waste and condition of the structure of the repository through the above-mentioned infiltration control system which is designed to be in operation within 375 years. No repair works on the galleries of the infiltration control system are envisaged except elementary maintenance of the waterproof coating. The system of pipelines to take way the penetrated water which is specified further above is constructed of standard elements which allow easy maintenance and replacement if necessary.

The condition of the protective multi-barrier coating shall be controlled not only visually but by methods of geodetic control and control over drainages which are part of it.

2.2.1.18 USING TECHNOLOGY APPROBATED IN PRACTICE

The technology for burial of radioactive waste in trench-type repositories is a modern technology well-approbated in practice. Contemporary trench-type repositories have been implemented in a number of developed countries with developed nuclear energy. There are such repositories in England, the USA, Japan, France and etc. Typical examples for such modern repository – surface multi-barrier modular trench-type repository are the repositories in Centre d'Obe-France, El Cabril – Spain, Mohovtse in Slovakia, Dukovani in Czech Republic, etc. [36]. Actually, this modern technology for burial of radioactive waste is developed in France – the country which has the biggest share of nuclear energy in the energy mix and it is a leader in radioactive waste management. The technology is based on the experience of France in construction and operation of La Manche repository which has been applied to the construction and operation of new French repository in Centre d'Obe which has a capacity of 1 million cubic metres of radioactive waste and it shall be in operation until 2040. The technology has been significantly developed during the construction of El Cabril repository which serves as a reference technology to the national trench-type repository (**Figure 2.2-20**). The same technology shall be used in a Belgian repository which is under construction (**Figure 2.2-21**).

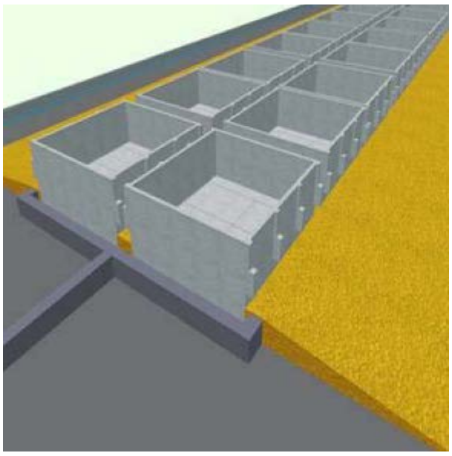
Centre d'Obe Repository, France

[36] Ira Stephanova, Burial of low- and intermediate-level radioactive waste, 2014

El Cabril Repository, Spain

FIGURE 2.2-20 CONTEMPORARY TRENCH-TYPE REPOSITORIES IN OPERATION

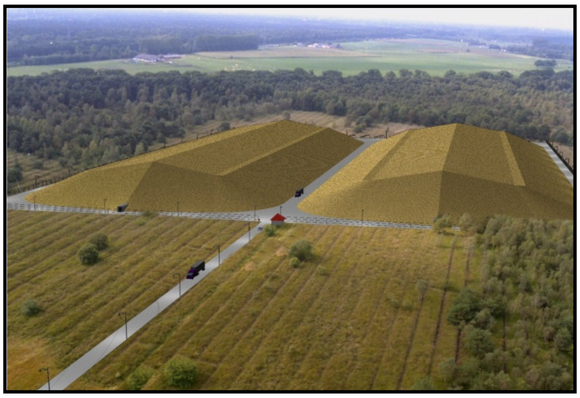
Appearance of the repository after its closure according to the project



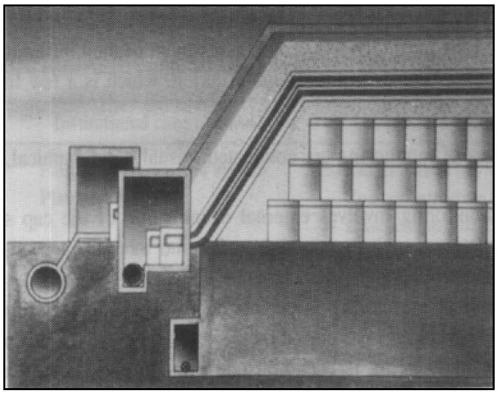
Apperance of the cells for burial of RAW according to the project

FIGURE 2.2-21 CONTEMPORARY TRENCH-TYPE REPOSITORY UNDER CONSTRUCTIONB, DESSEL, BELGIUM

The closure of a trench-type repository and construction of a protective multi-barrier coating is also a technology tested in practice and it has proved its efficiency as it is presented in an example of closed repository, La Manche, France in **Figure 2.2-22**.



Appearance



Details of the protective coating

FIGURE 2.2-22 CLOSED MODULAR TRENCH-TYPE REPOSITORY WITH A PROTECTIVE MULTI-BARRIER COATING

This shows that the use of the so-proposed technology for burial of radioactive waste in a trench-type repository conforms to the requirements of the Act on the use of nuclear energy[37] related to the use of technologies corresponding to the internationally recognised operational experience.

2.2.2 TECHNOLOGY FOR BURIAL OF LOW- AND INTERMEDIATE-LEVEL RAW IN A TUNNEL-TYPE REPOSITORY

2.2.2.1 STRUCTURE OF A TUNNEL-TYPE REPOSITORY

The technology of a tunnel-type repository is based on underground parallel tunnel workings (galleries) with large section (6.5 m.) and large length of 1130 m and the access to them is carried out through horizontal stulms which have small diameter (3.7 m).

The repository consists of 8 parallel tunnel workings for disposal of containers with radioactive waste (RCC), each one is 1130 long and has diameter of 6.5 m. The tunnel workings for disposal of RCC are disposed along the Radiana site, parallel to the road. The service of the tunnel workings for burial of RCC is carried out by 3 servicing galleries which are disposed perpendicularly - a transport stulm, service gallery, ventilation stulm which have a diameter of 3.7 m. An experimental stulm shall be built additionally which is specified further below and the total length of the mining workings amounts to 9 770 m.

The tunnel workings are disposed in one plane in a depth of 25-30 m under the surface of the terrain.

According to the design, the tunnel workings are disposed in loam at 5-10 m over the sandy and gravel Quaternary deposits. The distance to the Pliocene clay is not more than 9 m. The disposal of the transport stulm which gets to the galleries for disposal of RAW is presented in **Figure 2.2-23**.

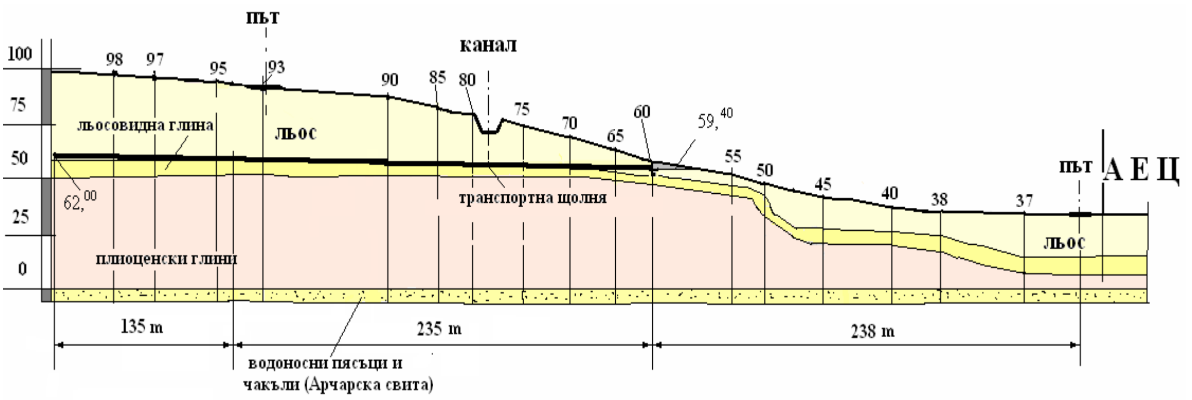


FIGURE 2.2-23 GEOLOGICAL SECTION WITH THE DISPOSAL OF THE TRANSPORT STULM

The scheme of the tunnel-type repository is presented in **Figure 2.2-24**. As it is presented further above, the repository consists of 8 parallel tunnel workings for disposal of radioactive waste. The distance between two galleries for disposal of radioactive waste (axis to axis) is 20 m and the size of the arch is 12.6 m. The access to the galleries is through a horizontal transport stulm starting from elevation 59.

[37] Act on the safe use of nuclear energy, Prom. SG No 63/28.06.2002, last amended SG No 68/02.08.2013

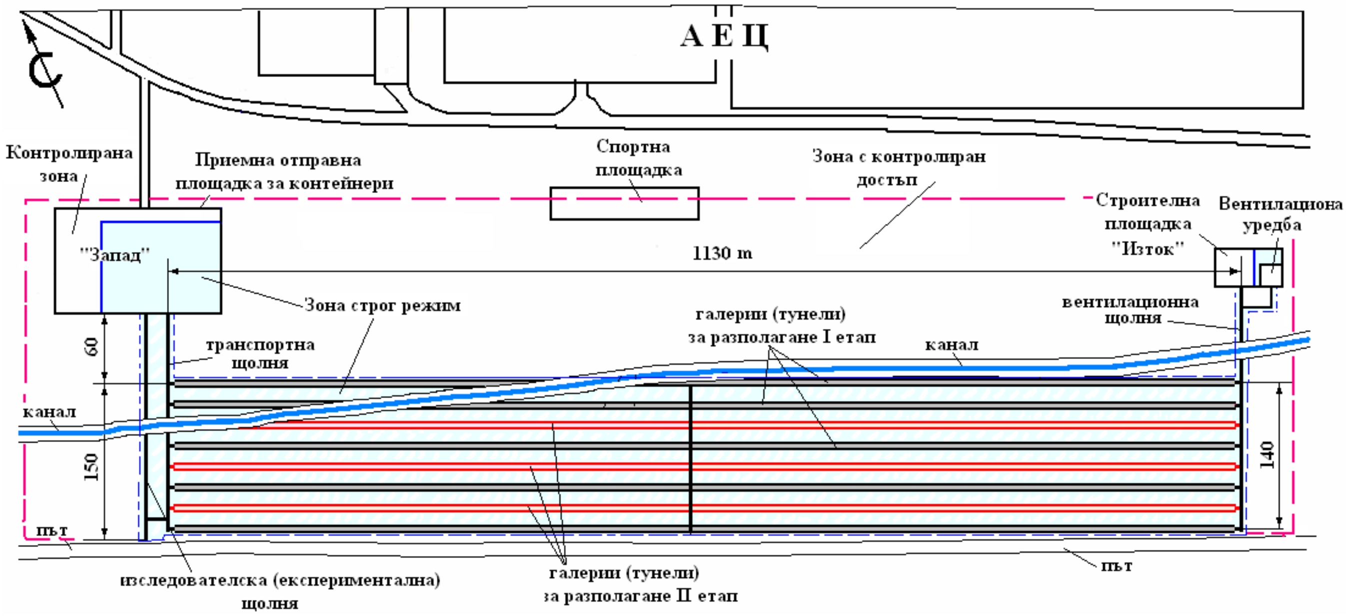


FIGURE 2.2-24 SCHEME OF DISPOSITION OF A TUNNEL-TYPE REPOSITORY

The provision of ventilation is obligatory for a tunnel-type repository. The ventilation is ensured by a perpendicularly disposed ventilation stulm with diameter of 3.7 m. (light section).

A service gallery is provided whose disposition is presented in **Figure 2.2-24** with diameter of 3.7 m. (light section)

The structure of the gallery for disposal of radioactive waste is presented in Figure **2.2-25**.

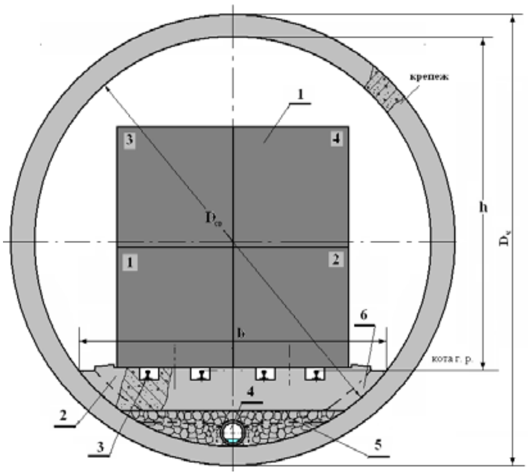


FIGURE 2.2-25 STRUCTURE OF THE GALLERY FOR BURIAL OF RADIOACTIVE WASTE

1 Container with RAW; 2 Foundation; 3 Railroad (wheel gauge 900 mm);4 Drainage for contaminated water 5 Rocks 6 Groundwater ditches

The tunnels for disposal of radioactive waste are equipped with a multi-layer, waterproof, reinforced concrete lining with total thickness of 0.45 m. The body is strengthened with micro-piles and injection silicification or cementation. The depth of the strengthening according to the authors of the paper is 40 cm.

A 40-cm concrete slab with drainage ditches which are part of the water collection system shall be constructed at the bottom part of the tunnel workings. The pipes to take the potentially contaminated water away shall pass under the concrete slab. The drainage water from the ditches and eventually contaminated water from the pipelines shall be managed separately and shall be discharged in separate receiving bodies located on the surface of the site which are equipped sampling devices. Before the start of the disposal of radioactive waste, it is considered as pure mining water and is discharged in a reservoir for pure water. After the disposal of the containers with radioactive waste, water is considered as potentially contaminated and is discharged into a reservoir for contaminated water. In order to facilitate the run-off, the galleries have a slight gradient of 5%.

As it is specified further above, the capacity of each tunnel is 2150 RCC. In each tunnel there are two sectors for radioactive waste and each one has a capacity of 1075 RCC separated by a service stulm (gallery). The containers are disposed lengthwise in the galleries for disposal in two rows, one on top of the other - four containers could fit in cross – section.

The servicing galleries – transport, ventilation and service have diameter of 3.7 m. The lining of the service underground workings is 0.33 m.

2.2.2.2 REPOSITORY CAPACITY

The tunnel-type repository consists of 8 tunnel workings (galleries) with length of 1130 m and each one has a capacity of 2150 RCC.

Total capacity of the repository amounts to 17 200 RCC. The capacity of the tunnel-type repository in the design is lower (1800 RCC less) than the necessary capacity of the repository (19 000 RCC) specified in part 1.7.3 in chapter 1.

2.2.2.3 AUXILIARY BUILDINGS AND FACILITIES

The auxiliary buildings and facilities are situated on the surface. They are situated in two sites with different functions. The so-called “Zapad” site includes the technological facilities for radioactive waste management and service buildings and facilities which are the same for two technologies for burial of radioactive waste and are specified in chapter 1. The charging station for remotely-controlled transport and lifting mechanisms and lamp-cabin – charging station for electrical lamps which are used by the operational personnel and construction workers are specific for the technology for disposal of radioactive waste in tunnels is.

“Iztok” site includes the mining and building complex, mining ventilation installation, water collection system. It includes: a charging station for battery locomotives, a workshop for maintenance of the construction equipment, compression ventilation installation, a site for overloading excavated earth mass, and a service gantry.

The reservoir for mine water and the reservoir for potentially contaminated water are located at “Iztok” site. The disposition of the reservoir for potentially contaminated water at “Iztok” site is in contradiction to the principles for radiation protection so that separation of “pure materials” flows from “radioactive contaminated or potentially radioactive contaminated” flows is needed. This location of the reservoir is determined by the gradient of the galleries for burial which follows the nature gradient of the layer where the tunnel is constructed and respectively it goes to the ventilation (drainage) stulm.

2.2.2.4 NECESSARY AREA AT RADIANA SITE

The tunnel-type repository is disposed on the area of Radiana site selected for the construction of a NDF according to DDP – Regulation and Building Plan. Taking into account the approach approved that the roads, which are used for transportation of radioactive waste, from the road controlled by Kozloduy NPP to the facilities for burial, should be within the site of the NDF, the necessary area amounts to 47.5 hectare.

In compliance with the requirements of the nuclear legislation, the entire Radiana site is considered as a site of nuclear facility where ground and shallow underground facilities are situated and the requirements for physical protection and rules and standards to ensure fire safety of the nuclear facilities are applied[38,39]. A system of fence facilities – warning, retarding and stopping fences equipped with technical devices for control and video surveillance shall be constructed. Before the construction, the site shall be cleared up from the existing trees and lower bushes and appropriate grass vegetation shall be planted. A drainage system for surface water - channels with rectangular sections from prefabricated concrete elements, which shall take away the stormwater into open reservoir, shall be constructed.

It is not suggested the use of additional area for the construction of the repository.

2.2.2.5 PASSIVE SYSTEMS TO ENSURE THE SAFETY

The passive systems to ensure safety are represented by the elements of the multi-barrier system. As elements of the multi-barrier system, the authors of the paper consider the following elements:

- **First engineering barrier** is the form of waste, which is cemented radioactive waste, some of which has already been put in steel drums with or without super pressure. The safety function of the form of waste (cemented matrix in which the waste is included) is connected with entry of radionuclides in the hard phase of the matrix as well as their detention by adsorption and precipitation in a highly alkaline environment of the cement. The cemented matrix is considered as chemical barrier which does not lose its safety functions for thousands of years.
- **Second engineering barrier** is a reinforced concrete container with thick walls, a bottom plate and a lid, where the cemented radioactive waste is put, with the free space between the cement matrix of the waste and the lid of the concrete container being filled with grout, forming a monolithic block. The reinforced concrete container should allow the extraction of waste in the period before the final closure of the NDF. The safety function is to ensure complete retention by maintaining mechanical integrity, incl. integrity of the clamps, for the period of operation of the repository, which shall be about 60 years. The reinforced concrete container maintains its functions of a chemical barrier for thousands of years.
- **Third engineering barrier** is the lining of the tunnel constructed by 40-cm waterproof concrete, filling material around the containers and strengthened area around the gallery for disposal whose thickness is 40 cm. The safety function is to preserve the mechanical integrity of the system for minimum 150 years, according to the authors of the paper.
- **Forth natural barrier** - is performed by the favourable characteristics of the site. The natural barrier is characterised by filtration rate in the range of $10^{-5} \div 10^{-6}$ m/s which is high enough to let the infiltration hydraulic flow within minimum 50 L/m^2 per year which corresponds to the vertical infiltration of 8.7 % of average annual precipitation.

[38] Ordinance on provision of physical protection of nuclear facilities, nuclear material and radioactive substances, SG No 77/3.09.2004, last amended. SG No 44/9.05.2008

[39] Ordinance № 7 /08.06.1998 on systems for physical protection at construction sites, SG No 70 / 19.06.1998

2.2.2.6 ACTIVE SYSTEMS TO ENSURE THE SAFETY

The tunnel-type repository is equipped with U-shaped (reverse flow) mine ventilation. The clean ventilation stream enters through the transport stulm, passes through the galleries for disposal and it is sucked up to the ventilation stulm by the main ventilation fan, which is working in suction mode.

2.2.2.7 DESCRIPTION OF THE PROCESS OF DISPOSAL OF RCC IN A TUNNELS

Activities related to the management of radioactive waste which are common for two technologies for burial of radioactive waste are specified in chapter 1. Specific activities, which are determined by the technology for burial, are described in this part.

The radioactive waste enters into the underground complex (tunnel-type repository for burial of radioactive waste) through a transport stulm and is transported to the place for disposal in the tunnel.

The transport and disposal is carried out by means of remotely controlled transport and unloading machine (heavy-duty forklift) moving along a rail. The transport and unloading machine moves along a railroad dug into the concrete foundation of the transport stulm (**Figure 2.2-26**) and the concrete foundation of the galleries for disposal of radioactive waste (**Figure 2.2-27**). The forklift is with upper grip of RCC, loading capacity of 25 ton and lifting height of 3 m which allows the disposal of the containers in two rows (**Figure 2.2-27**). The observation of the process of transport and disposal is carried out by means of video surveillance cameras.

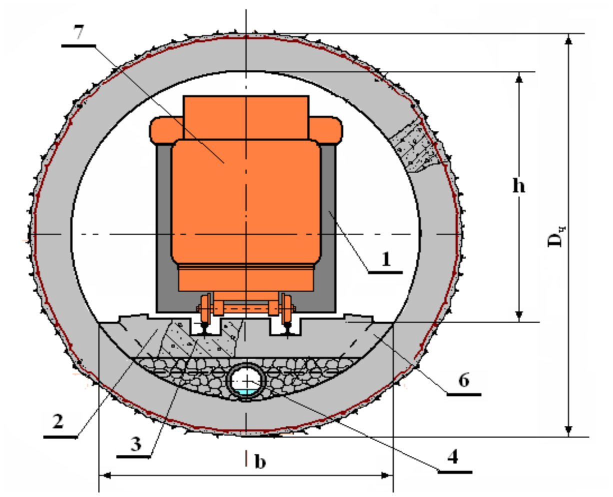


FIGURE 2.2-26 CROSS SECTION OF THE TRANSPORT STULM IN THE TUNNEL-TYPE NDF

1 Container with RAW 2 Foundation 3 Railroad (wheel gauge 900 mm) 4 Groundwater drainage pipe 7 Robotic transport and unloading machine

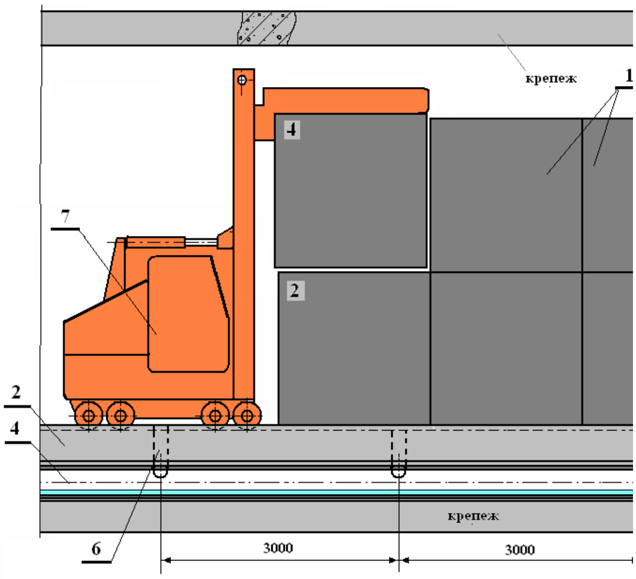


FIGURE 2.2-27 TECHNOLOGY FOR STORAGE OF RCC IN A TUNNEL-TYPE NDF

1 Container with RAW 2 Foundation 3 Railroad (wheel gauge 900 mm; 4 Groundwater drainage pipe 5 Rock (crushed stone) and tubes for contaminated water; 6 Groundwater channels

2.2.2.8 INFILTRATION CONTROL SYSTEM

According to the authors of the paper, potentially contaminated water is caught during the operation of tunnel-type repository by the longitudinal channels (gutters) in which rails of the transport and unloading vehicle are installed. Every 50 m the water is discharged into a pipeline system constructed under the concrete foundation on which the containers with waste are placed. The pipeline system is taken away through a ventilation stulm to the collection reservoir which is situated in the heading of the ventilation stulm. A building, in which a reservoir for contaminated water shall be situated, is envisaged at “Iztok” site.

The pipeline system should be constructed so that it could control from which sector of the repository the contaminated water shall enter. At this stage of the investment proposal, it is not clear how it shall be carried out but it is assumed that at the next stage of the development of the project technical means to control the outlet of each pipeline shall be designed.

Water from pipeline system is considered as potentially contaminated and is controlled for the presence of radioactive pollution. As it is specified in chapter 1 of the present REIA, the processing of radioactive waste is not envisaged in the NDF. In case of presence of radiation pollution, water shall be transported to SU RAW-Kozloduy for processing. Pure water is taken away in storm water reservoir.

The so-designed pipeline system does not allow exercising control over its condition and respectively the detection of faults or failures during the 60 years of operation. The pipeline system is made of standard materials and it is relied on its performance to be maintained for 60-year period of operation. This is ensured only by means of quality assurance in the process of construction. Taking into account the large number of pipelines (over 180) the possibility of defects or failure is large and there is a lack of technical possibility to replace a defective pipeline in practice.

The pipeline system is demounted at the closure of the repository. After the closure of the repository, the drainage of potentially contaminated water from tunnels with radioactive waste is executed by gravity in direction of the ventilation (drainage) stulm filled with inert material and is taken away to a reservoir located at the bottom of the ventilation shaft which according to the authors of the paper has significant capacity and it is filled with pervious material. Then water passes through porous concrete and penetrates into the host massif.

2.2.2.9 CONTROL AND MONITORING METHODS DURING THE OPERATION OF NDF

According to the authors of the paper the following activities shall be implemented during the operation of the repository:

(1) radiation monitoring of the site and surveillance area which does not depend on the type of the repository (tunnel-type or trench-type) and it is specified in chapter 1 of the present REIA;

(2) hydrological monitoring – it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

(3) seismic monitoring – it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

(4) meteorological monitoring on the site - it does not depend on the type of the repository and it is specified in chapter 1 of the present REIA;

The direct control over the condition of the tunnels for burial of radioactive waste could be exercised until the disposal of RCC. After the disposal of the packages with radioactive waste, the exercising of control over both condition of the packages and condition of the tunnels in which RCC are buried is impossible. Therefore, the authors of paper propose the control over the condition of the tunnels with RCC to be mediated by examining micro deformations and stress-strain state in the massif by non-destructive methods in the experimental stulm.

The control over the water condition, by which the condition of the packages with radioactive waste could be determined, is momentary only in the process of filling of specific tunnel working according to the proposed conception for closure. After the closure of a specific tunnel during the operational period of the repository, the control over the entire water quantity, coming from it, is possible but the condition of the packages and engineering barriers (lining, strengthened area) in the individual sections of the tunnel could not be controlled. Therefore, the authors of the paper propose the control over the condition of the radioactive waste to be mediated by control over limited number of RCC located in the experimental stulm. The disadvantage of this proposal, apart from the mediated control, is the different geometry of the galleries for burial and the experimental stulm which do not allow direct use of the results.

2.2.2.10 EXTRACTION OF RCC DURING OPERATION

Pursuant to the requirements of the nuclear legislation[40], the design of the repository for burial of radioactive waste should provide a possibility for extraction of the packages with radioactive waste during the operation of the repository. This includes two aspects:

(1) A possibility to extract the entire quantity of waste in the facility;

(2) A possibility to extract the future defective package/packages.

Theoretically, the extraction is possible in both aspects although it shall be very difficult. In the first aspect the extraction of the entire quantity is very difficult in the closed tunnels due to the presence of a large quantity of filling material which not only causes technical difficulties but results to longer stay of the personnel who participates in the operations related to extraction with all the associated risks to their health. The lack of general ventilation in the closed tunnels and the need of use of local ventilation cause an additional risk. In case of deformation of the tunnel which is likely to happen due to the construction of the tunnels in weak rocks (loam), it should be expected that the transport and lifting equipment could not be used to supply other technical means.

The possibility to extract any defective package / packages is also theoretically ensured but it is connected with the extraction of a significantly larger number of packages (1075) until it reaches the problematic package and related significant radiation dose exposure to personnel.

2.2.2.11 NEED OF TEST FACILITIES BEFORE THE CONSTRUCTION OF THE TUNNEL-TYPE REPOSITORY

It is envisaged faster construction of the experimental stulm before the construction of the tunnel-type repository in view of *in situ* study on the interaction underground working – host massif and determining the stress that shall occur in the massif. Although standard mining methods shall be used during the construction, the authors of the paper think that testing of different methods of tunneling and strengthening is necessary which the experimental stulm shall be used for.

2.2.2.12 CONSTRUCTION OF A TUNNEL-TYPE REPOSITORY

The construction is executed by means of standard mining methods using machines that are presented in **Appendix 8-II.6.** The excavated earth is taken away by small wagons (2.8 m^3) moved by mine battery locomotives to “Iztok” construction site by railroad which is used only for the constriction and it is demounted later. In the start of the mine construction, the ventilation is done by mine ventilation fans for local ventilation located close to the mouth of the galleries. After the construction of the transport stulm, ventilation stulm and pilot working of the farthest tunnel working from the mouth, the mine ventilation is commissioned. The construction of the tunnels for burial of radioactive waste is two-stage process which includes: construction of the so-called pilot working with small diameter (4.00 m); lying temporary lining; waiting 4 to 6 months the stress to be balanced; widening up to the required diameter (7.40 m) and lying the final multilayer lining. It is essential, having in mind the requirements to the concrete for underground workings, not to be transported by concrete trucks but to be prepared on the surface using a specific technology.

[40]. Ordinance on safe management of radioactive waste SG No 76/30.08.2013

A significant part of the process of construction of the tunnel-type repository is the strengthening of the rocks close to the mine workings. This is necessary because the construction of the tunnels is inevitably accompanied by intense fracturing in the depth of the massif. Even in the most plastic geological environment around the working a so-called zone of inelastic deformations is formed in which the following zones could be observed sequentially: (1) an area of partial and complete destruction; (2) area of intense crack or stratification; (3) area of plastic deformations. The authors of the paper propose the strengthening to be carried out by anchoring micro piles and subsequent silicification (injection of water glass and other additives), or cementation (injection of grout). In either case, injection is performed by the injector devices under pressure. The thickness of the strengthened area, according to the authors of the paper, is 40 cm.

2.2.2.13 EARTH MASSES AND HUMUS MANAGEMENT

According to the authors of the design 70 200 m^3 humus shall be obtained during the construction of a tunnel-type repository together with facilities and infrastructure at the site and 43 800 m^3 out of 70 200 m^3 shall be used again during the reclamation of the site and its closure. The authors of the paper propose a landfill for humus material to be constructed which shall be used for the reclamation during the closure of the repository after 60-year operational period. This proposal is in contradiction to Ordinance № 26 on reclamation of disturbed areas, improvement of low productive lands, removal and utilization of the humus layer[41], which forbids the storage of humus layer in landfills for more than 15 years.

The surplus of humus in the amount of 26 340 m^3 could be used in different enrichment activities in nearby settlements.

According to the authors of the design, the volume of the surplus of earth masses which should be disposed (the earth mass to be disposed in a heap outside Radiana site amounts to 650 000 m^3). This quantity is twice as much as the available options to provide places for disposal of earth masses, identified in the research made[42].

2.2.2.14 STAGES IN CONSTRUCTION OF A TUNNEL-TYPE NDF

According to the authors of the design, the tunnel-type repository shall be constructed in the following three stages:

- → Stage 1 includes construction of the first two tunnel workings and infrastructure at the site; in stage 1 the capacity is 4300 RCC;
- → Stage 2 includes operation of 2 tunnel workings which have been already constructed and construction of three galleries for disposal of RAW; the total capacity is 10 750 RCC in second stage;
- → Stage 3 includes construction of last three galleries (tunnels) for burial of RAW in parallel with the operation of the existing ones; the total capacity of the repository is 17 200 RCC.

Taking into account the obvious need of larger capacity for burial of radioactive waste during the first stage of the construction of a NDF determined by the need to bury radioactive waste from decommissioning of Unit 1-4, the above- mentioned line should be changed and three galleries (tunnels) for burial of RAW with a capacity of 6450 RCC to be constructed during the first stage.

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[41] Ordinance № 26 on reclamation of disturbed areas, improvement of low productive lands, removal and utilization of the humus layer, prom. SG No 89 /22.10.1996, amend. and suppl. SG No 30/2002);

[42] Geoconsult OOD, 2014 Research on the location of a landfill for surplus soil and temporary landfills for humus and loess;

During the second and third stage, the construction of galleries for burial of radioactive waste shall be executed only through the ventilation stulm to minimize to possible extent the mixing of operational activities in the repository and building activities. The scheme for construction of new tunnels during the operation of the repository is presented in **Figure 2.2-28**. However, the separation of airflows is not provided. The airflows coming from the galleries where RAW is buried mix with airflows coming from galleries which are under construction and there shall be possible impact on the construction workers of new galleries which are not qualified to work in the field of ionizing radiation.

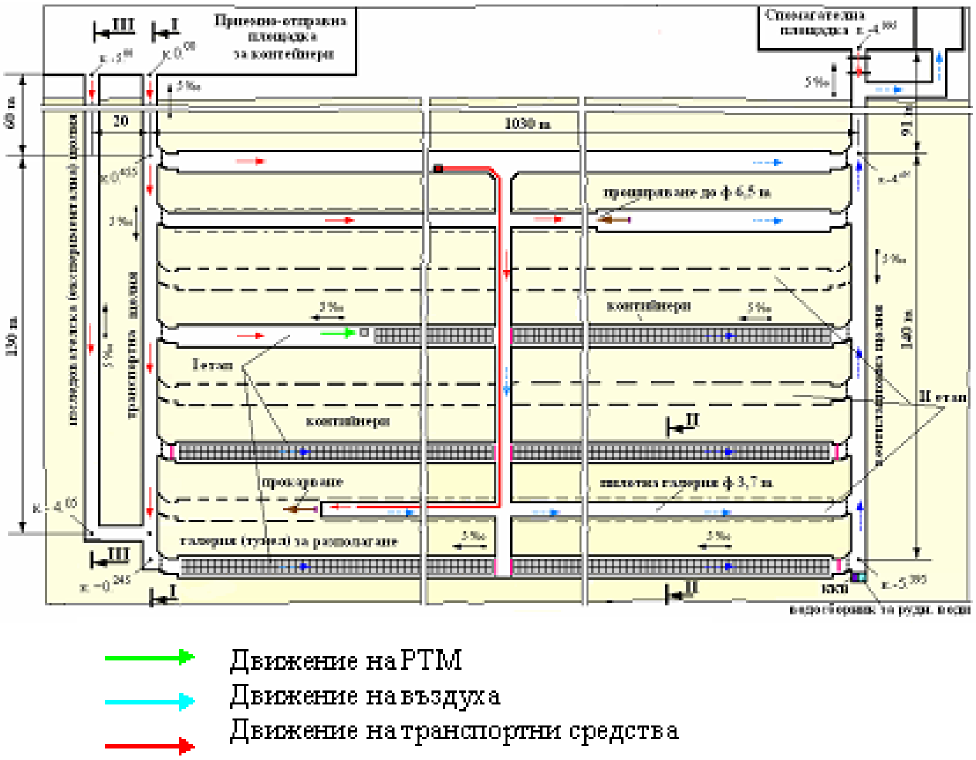

FIGURE 2.2-28 CONSTRUCTION OF NEW GALLERIES FOR BURIAL OF RAW DURING THE OPERATION OF EXISTING GALLERIES OF TUNNEL-TYPE REPOSITORY

2.2.2.15 NEED OF TEST FACILITIES BEFORE THE CLOSURE OF A TUNNEL-TYPE REPOSITORY

During the operation of the repository, tests on different materials for filling the empty space in the tunnels with buried radioactive waste shall be made. The tests shall be made in the experimental stulm.

2.2.2.16 CLOSURE OF A TUNNEL-TYPE REPOSITORY

In compliance with the requirement of the nuclear legislation[43,44] the closure of a repository for burial of radioactive waste shall be carried out pursuant to the technical design for closure, closure plan and safety assessment, which are approved by Nuclear Regulatory Agency and after individual safety assessment during closure. The process of closure of the NDF and requirements to it are

[43] Ordinance on safe management of radioactive waste SG No 76/30.08.2013

[44] Ordinance on the procedure and issuance of licenses and permits for safe use of nuclear energy, prom. SG No 41/18.05.2004, last amend. SG No 76/76/5.10.2012

specified in detail in chapter 1. The specific characteristics of the closure of the tunnel-type repository are specified in the present part.

According to the authors of the paper, the closure of the repository is carried out in stages by successive filling with a filling material and sealing the entrances during operation using standard pneumatic and hydraulic handling equipment. The closure takes place in the manner described below. The appearance of the filled repository is presented in **Figure 2.2-29**.

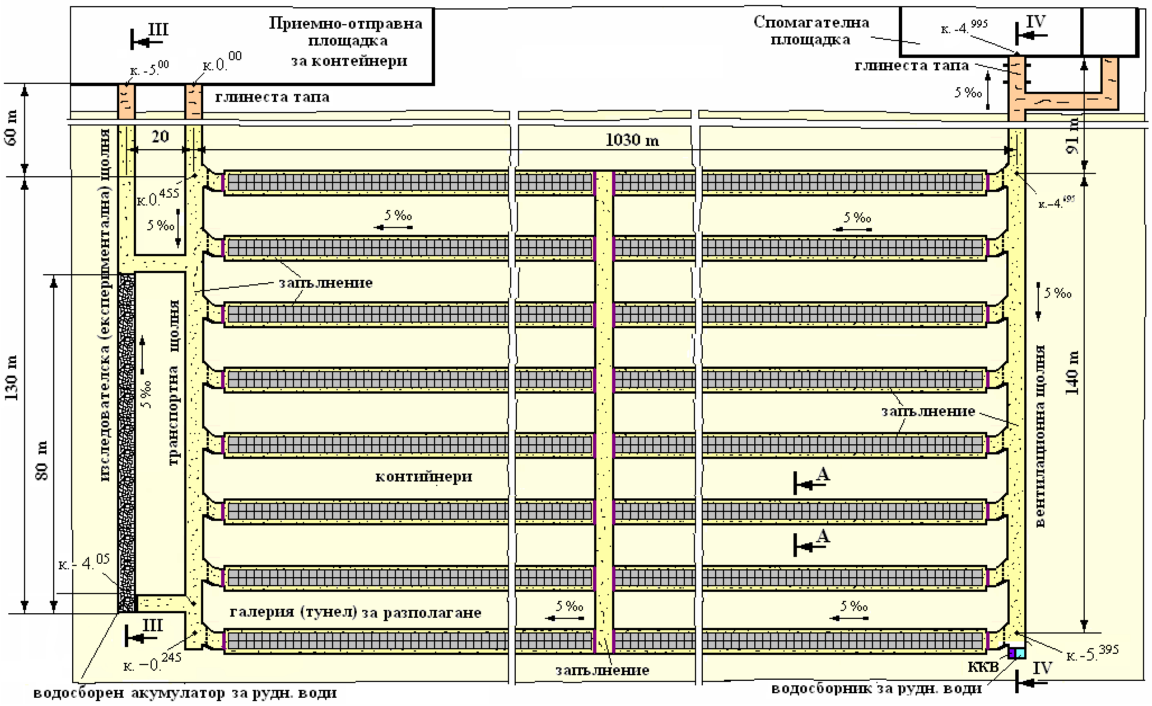

FIGURE 2.2-29 LONGITUDINAL SECTION OF THE FILLED TUNNEL-TYPE REPOSITORY

The closure is carried out as follows:

(1) Drainage pipes are demounted in the tunnels; the system does not allow dismantling of the railroad situated under the containers with radioactive waste. According to the authors of the paper, railroads are subject to corrosion by the formation of iron hydroxides which can enhance the migration of radionuclides;

(2) Tunnels where the radioactive waste is buried are filled with filling material;

(3) Entrances of the tunnels where the radioactive waste is buried are sealed with a clay “cap” and concrete walls. The clay caps are standard mine technology. They are 30-m structure limited on both sides by reinforced concrete walls, 35 cm thick, inside of which at every 10 m 2 such reinforced concrete separation walls, which are 35 cm thick, are built. The space between the separation walls shall be filled with clay slurry by compression pump.

(4) After filling with filling material all tunnels where radioactive waste is buried, the facilities in the ventilation and transport stulm are demounted incl. the railroad, the other equipment, which according to the authors of the paper is subject to corrosion by the formation of iron hydroxides which can enhance the migration of radionuclides. The stulms are filled with inert material. Clay caps are constructed and their last reinforced concrete barrier is at the entrance of the stulm;

(5) Water which is eventually caught in the repository or generated as a result of dehydration of the filling material and packages are taken away into the heading of the ventilation gallery

where there is a concrete reservoir with sufficient capacity and filled with absorbent material;

The most important of the above-mentioned operations is the filling of the empty space between the walls of the module and radioactive waste. It should be performed in such way to guarantee the lack of free space which later could be filled with water penetrating through the walls.

The filling is executed in two stages. Firstly, the whole space is filled with the basic filling material. It should wait for a while to develop the processes of self-compaction and settling and after that the other free space is filled with clay. The scheme of filled repository in cross section is presented in **Figure 2.2-30.**

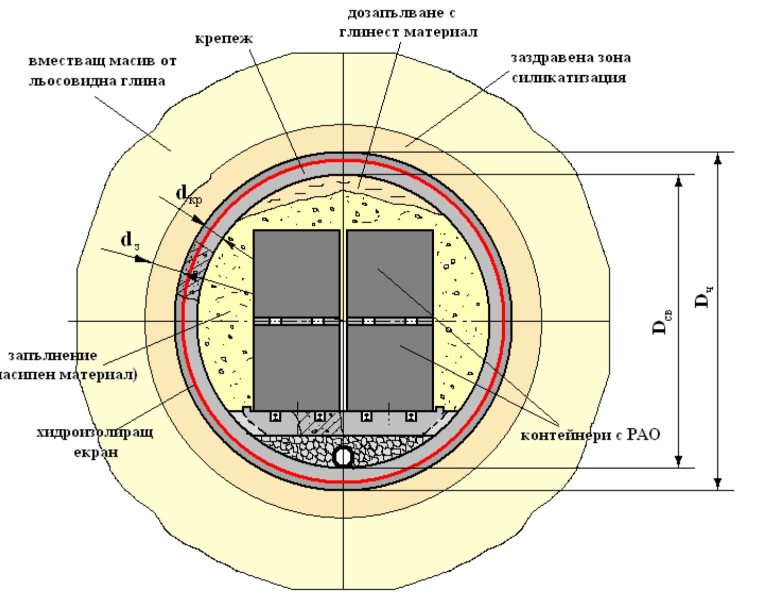

FIGURE 2.2-30 CROSS SECTION OF A FILLED TUNNEL-TYPE REPOSITORY

Two technological options are proposed for a basic filling material at this stage of the investment proposal:

(1) Filing with loess-cement hydromixture which is made in filling complex consisting of a mixer with proportioners. The materials are added under pressure through a pipeline with internal diameter of Ø150 mm and length of around 1500 m;

(2) Filling with granular bulk material – ceramsite. The addition of the granular bulk material is performed in a similar manner - under pressure through a pipeline with internal diameter of Ø150 mm and length of around 1500 m;

To implement the filling according to two above-mentioned manners, a pipeline moving along a monorail is mounted in the upper edge of the arch before the beginning of the disposal of the containers with RAW in the galleries. The pipeline consists of units and each of them is 2 m long and made of thick-walled pipes PVC Ø200/8,0 type 100. During the filling of the space around each two rows of containers (4 m), the pipeline is pulled out and shortened around 4 m. the filling and shortening of the pipeline is done from the service stulm situated in the middle of the repository. According to the authors of the paper, the technology of filling has been tested for standard mine tunnels but it has not been applied to long tunnels in which radioactive waste is disposed. It has not been clarified the issue regarding the filling with clay of free space which is left after self-compaction and settling of the basic filling material. The authors of the paper suggest that the filling shall be executed in analogical manner to the filling with the basic filling material but they have not proposed technical means for it.

The monorail which moves along the above-mentioned pipeline is not demounted and it is a source of corrosion which accelerates the migration of the radionuclides.

According to the authors of the design, the access of water to the tunnel-type repository is ensured by the geological environment above the tunnels which probably it shall not be damaged during the process of construction and operation. The natural barrier is characterized by infiltration rate in range of $10^{-5} \div 10^{-6}$ m/s which is high enough to let the infiltration hydraulic flow within the minimum 50 L/m^2 a year which corresponds to the vertical infiltration which amounts to 8.7 % of average precipitations. The water quantity that could get to the packages with radioactive waste is over 30 times higher compared to the trench-type repository.

2.2.2.17 METHODS RELATED TO CONTROL AND MONITORING DURING THE PERIOD OF INSTITUTIONAL CONTROL

The activities during the institutional control which are the same for two types of repositories (tunnel-type and trench-type) are specified in chapter 1 of the present REIA.

Taking into account the specifics of the facility, the control over groundwater passing through the tunnels with radioactive waste is impossible which means that direct conclusions for the condition of tunnels cannot be made. Therefore the authors of the paper propose the experimental stulm to continue to be in operation during the entire period of institutional control and the above-mentioned experiments in item 2.2.2.9 - *Control and monitoring methods during the operation of NDF* to be made in it and on the basis of these methods to be made indirect conclusions for the condition of tunnels. The disadvantage of this proposal apart from indirect conclusions is the different geometry of the galleries for burial and experimental stulm which questions the applicability of indirect analysis.

2.2.2.18 USING TECHNOLOGY APPROBATED IN PRACTICE

The proposed technical solution is a new technology which has not been applied for burial of radioactive so far.

There are a small number of planned or constructed tunnel-type repositories for burial of radioactive waste from the operation and decommissioning of nuclear plants worldwide. All tunnel-type repositories are in hard rocks situated in significant depth and have different type of construction. As examples of such repositories, we can present two repositories in Finland located in solid intact massif of tornalite - 70 m deep and solid homogeneous granite - 110 m deep as well as the repositories in Sweden and Norway in hard rock in depth of 50 m. The radioactive waste is disposed in silos with limited volume hollowed out by tunnel workings or in short tunnels – 40-100 m long which are also constructed by tunnel workings.

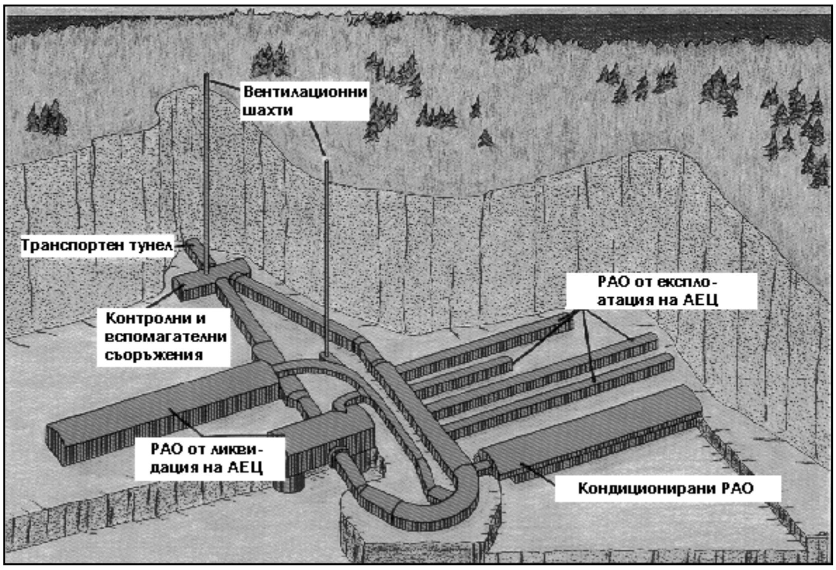

FIGURE 2.2-31 A TUNNEL-TYPE REPOSITORY, LOVIISA, FINLAND

The appearance of the typical tunnel-type repository which is in operation in Loviisa, Finland is presented in **Figure 2.2-31**[45]

There are no examples of repositories in soft rocks especially in loess massif which is considered as weak soil in the depth of 23-30 m under the surface as well as the use of extremely long tunnel workings (1130 m) for burial of radioactive waste.

This shows that the so-proposed technology for burial of radioactive waste in a tunnel-type repository does not conform to the requirements of the Act on the safe use of nuclear energy[46] to use technologies corresponding to the internationally recognised operational experience.

[45] Ira Stephanova, Burial of low- and intermediate-level radioactive waste, 2014

[46] Act on the safe use of nuclear energy, Prom. SG No 63/28.06.2002, last amended SG No 68/02.08.2013