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Report for RAWRA Board

Notation : 04/50

RESEARCH & DEVELOPMENT PLAN

Submitted in connection with :	Preparation of the Plan of Activities and RAWRA Budget for 2007 and Subsequent Years
Interval :	
Proposal of the Board decision :	RAWRA Board takes account of the submitted Report.

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1 INTRODUCTION

Preparation of the geological repository proceeds in accordance with the Concept of RAW and SNF Management in the Czech Republic, approved by the Government Decree No. 487 of 15 May 2002 and in compliance with the three-year and long-term plans of the Radioactive Waste Repository Authority, approved by the Government Decree No. 1541 of 30 November 2005. Research and development activities are a part of the geological repository development program the objective of which is to provide scientific and technical prerequisites for the deep disposal of HLW and SNF and to support the understanding and acceptability of the geological disposal of HLW and SNF.

The "Regional Development Strategy" approved by the Government (Government Decree No. 561 of 17 May 2006) is an important document in the search for a suitable site for the geological repository.

The geological repository development program is accomplished in several steps and it is subdivided into the following topics:

a) selection of a suitable site and determination of its characteristics, including the verification of the geological environment stability and homogeneity,
b) proposal of the repository design, including materials and composition of the engineered barriers,
c) safety case and evaluation of the disposal system,
d) the related technical research and development.

This itemization is used not only in this document but also in the RAWRA activity plans. The main targets and priorities of research and development until 2015 are as follows:

Target	Deadline
Finding of sites with the best geological conditions, in conformance with the preservation of the assumed development of the area under interest. After the evaluation of the respective results to include two sites (main and reserve) for the geological repository into the land use plans	**2015**
Based on the results of both domestic and foreign research and development studies to update the design of the geological repository with the aim to prove its viability and safety	**2012**

For the needs of the disposal system design, research and development and for the elaboration of the safety case the disposal system is usually divided as follows:

SNF matrix HLW matrix	Container	Buffer	Backfill	Excavation disturbed zone (EDZ)	Geosphere
Near field					Far field

This classification is also used in the subsequent parts of this document.

2 ADMINISTRATION OF THE DGR DEVELOPMENT PROGRAM

In the RAWRA administrative system the Department of the Development of the HLW/SNF Geological Repository (henceforth Department 0400) is responsible for the conceptual design and implementation of the geological repository development and for the coordination of research and development in the field of RAW management. With this aim it provides particularly for:

- the designing and investments connected with the selection of the geological repository site,
- the geological repository design and its updating in dependence on the research and development achievements,
- the international cooperation within the framework of its activities,
- it prepares the basic data for the RAWRA activity plans and financial plans,
- it works out an proposal of the research and development concept in the field of the geological disposal of HLW and SNF and in the related fields (SNF reprocessing, transmutations),
- the actual, financial, and professional control of the research and development programs,
- it prepares the basic documents for the planning and contracting of the research and development projects - assigning, checkup, evaluation, cooperation in the solution and preparation of summary reports,
- it prepares the respective control documents

In the field of safety analyses the Department 0400 cooperates with the Department of Safety and Licensing (Dept. 0500). Moreover, links to the Department of Planning and Budget (Dept. 0200) as well as to the PR experts (Dept. 0100) are established. At present the Department comprises the following experts:

Department of the HLW/SNF geological repository preparation *(5)*		**Education**	**Profession**	**Responsibility for**
0401	Senior expert for the project management and technical development, Head of the Department	University	geology	Coordination of research and development works and works in geology
0402	Expert for technical development, Deputy Head of the Department	University	geotechnology	Designing of the repository system solution and development of the engineered barriers (near field)
0403	Expert for technical development	University	chemistry	Supplementary research and development (SNF reprocessing and transmutation technology)
0404	Expert for the data analysis and administration	University	geology	Data administration (GIS) and research in the field of the geological environment (far field)
0405	Program assistant	High school		Data administration and archive of documentation

Mutual coordination and interconnection of the individual projects is solved at the level of the Head of the Department 0400 and by the respective contracts with the suppliers of the research and development works. In the case of the contracts it is usually worked out in

detail in the respective research project plan or in the quality management program for the respective research.

The following disciplines could be rated among the important branches required for the geological repository development program:

- geology, structural geology, petrology, and rock mechanics
- hydrology and hydrogeology
- geochemistry, hydrogeochemistry, and microbiology
- designing of industrial buildings and mine excavations
- material technology and manufacturing technology of containers
- long-term behaviour of a container and buffer materials
- fuel and its dissolution, nuclear chemistry
- repository impacts on the geosphere
- working out of analyses and evaluation of the repository system behaviour and safety analyses
- spreading of radionuclides in the environment and the assessment of the environmental impacts of constructions

Furthermore, it is necessary to have knowledge in the field of planning and project administration.

For the future administration of the project RAWRA anticipates enhancement of the Department 0400 in the field of the repository system designing and in the development of engineered barriers and of the Department 0500 in the field of modelling and safety analyses.

RAWRA implements the quality management system. For the geological repository development program the following managing documents have been issued:

- PJ.J.01 - Quality assurance program of the research and development projects
- PJ.S.21 - Quality assurance program for the geological repository site selection

RAWRA provides for a sufficient qualification of its employees and its enhancement. The professional education of employees proceeds either by acquiring the respective knowledge in its practical application or by courses and special training, or - possibly - by their participation on international ventures. Direct superiors of individual employees are responsible for the identification of schooling and training needs. For simpler activities schooling and training could be substituted by long-term practice.

An Expert Board has been established to assess the plans and priorities of the geological repository research and development program and to evaluate the quality of the achieved results. The Expert Board works out an objective and unprejudiced standpoint to the geological repository development program and to the scientific and research projects results for the RAWRA Director and for RAWRA Board. In addition to the evaluation of the programs mentioned above, the Expert Board can submit its own recommendations.

3 INTERNATIONAL RESEARCH AND DEVELOPMENT ASPECTS

International institutions coordinate a number of activities in the field of RAW management, they initiate legislative and regulative activities, and - last but not least - they provide a platform for meetings of experts and for mutual exchange of information. It is therefore extremely important to be in contact and to participate in a reasonable extent in the activities of these organizations.

IAEA (International Atomic Energy Agency)

IAEA is an international agency of UNO serving as a world leading forum for the scientific and technical cooperation in peaceful uses of nuclear technology. An integrated program for management with radioactive waste exists in IAEA. This program provides a support to the Member States, particularly by organizing an exchange and propagation of technical, safety, and legislative information, by providing instructions, technical assistance, and training, and by supporting research and development in this field. In the Czech Republic State Office of Nuclear Safety (SÚJB) is a competent administrative body for the coordination of contacts with IAEA. RAWRA participates on the preparation of materials and on the coordinated research programs. It also delegates its experts to the technical committees and IAEA missions and to their participation in the meetings of consultants or advisory groups. In the field of the geological disposal of RAW a number of IAEA documents are relevant and RAWRA uses them in its activities. Namely:

- The Principles of Radioactive Waste Management, Safety standards No. 111 - F, 1995
- Classification of Radioactive Waste, Safety standards No. 111-G-1.1, 1994
- Geological Disposal of Radioactive Waste, Safety standards No. WS-R-4, 2006
- Scientific and Technical Basis for the Geological Disposal of Radioactive Wastes, TRS No. 413, 2003
- Siting of Geological Disposal Facilities, Safety standards No. 111-G-4.1, 1994
- Implications of partitioning and transmutation in radioactive waste management, TRS No. 435, 2004

OECD/NEA (Organization for Economic Cooperation and Development/Nuclear Energy Agency).

In the field of the radioactive waste management the agency organizes a number of programs orientated to selected issues that are financed from the participants' funds. The role of NEA/OECD lies first of all in the determination of directions and in the support of common activities of the Member and Affiliated States resulting in the enhancement and systemization of professional knowledge in the given field. RAWRA organizes the participation of its representatives in selected projects and sometimes it participates on the financing of certain projects (for instance, of the project of thermodynamic database - TDb).

- RWMC (Radioactive Waste Management Committee)

  A NEA-OECD managing committee for the RW management. It consists of the representatives of 23 OECD Member States and of the representatives of IAEA and EC. RWMC coordinates the activities of permanent working groups and of the ad hoc established so-called Task Groups.
  RAWRA's activities in this group are executed by the Department 0600 - Department of Technical Assistance.

- IGSC (Integration Group for Safety Case)

  The Group directs programs connected with the assessment of the long-term safety of the geological repository. RAWRA's activities in this Group are executed by means of the Department 0500 - Department of Safety and Licensing.

- TDb (Thermodynamic data base)

  Project TDb is orientated to the collection of input data on the chemical reactivity of selected elements contained in the radioactive waste. The data are assigned for advanced modelling and analysis of the disposal system.

EC (European Commission)

Most of the Commission's activities in the field of the nuclear energy exploitation are based on the Euratom Agreement. They are aimed to supporting research and spreading of technological information, to providing unified safety standards for the health protection of workers and population and to organizing the fulfilment of these measures. The Commission strives to establish links between states and international organizations in order to ensure progress in the peaceful uses of nuclear energy. Its program in the field of RAW management comprises in particular:

- permanent analysis of the technical achievement in the RAW management and provision of updated information on the actual state of works and obtained results in all EU Member States,
- monitoring of the measures leading to the realization of a long-term or permanent storage of radioactive waste under optimum conditions,
- consultations with the aim to acquire maximum advantage from the national and international programs and EC programs,
- provision of the EC research and development programs continuity by means of the general plans of the science and research support,
- provision of information to the general public.

The projects worked out in the general plans of the science and research support play a key role in the field of research and development. For RAWRA the results in the field of the RAW management of the already finished projects of the 5th general plan (namely FEBEX II, PROTOTYPE REPOSITORY, CONTAINER CORROSION, COBECOMA, IN-CAN PROCESSES, SFS, BENIPA, BENCHPAR, BIOCLIM, BioMoSA, SPIN, PADAMOT, RETROCK) and of the projects of the 6th general plan presently under progress (namely NF-

PRO, FUNMIG, ESDRED, PAMINA, EUROPART, RED-IMPACT, ACTINED, COWAM II) are particularly important. The orientation and results of the projects are available on the web pages http://cordis.europa.eu/fp6-euratom/ev120303.htm. The results of the respective projects worked out in the framework of the 7th general plan beginning in 2007 will be also used.

Foreign agencies for RW disposal

Cooperation with foreign agencies has a great importance for the effective research and development works. Due to the fact that the DGR development program in the Czech Republic is delayed in time in comparison with a number of foreign programs, RAWRA can use up the experience acquired by these agencies in the site selection and disposal systems development. The cooperation with SKB, POSIVA, and NAGRA has a particular importance for the practical orientation of research and development.

SKB (Sweden) and POSIVA (Finland)

Both these countries plan SNF disposal in granite formations. POSIVA selected a site for the geological repository (Olkiluoto), SKB is deciding between two sites (Östhammar, Oskarhamn). POSIVA started the excavation of the underground laboratory (Onkalo) in the Olkiluoto locality. Both countries expect to put the repository into operation in 2020.

The disposal system is based on a container, with the outer 5-cm copper shell. From the point of view of designing the system is finished and is subjected to safety assessment (e.g., SKB - SR 97). Tests of the container manufacturing and of the copper shell welding methods (friction welding) are under progress in the so-called Canister Laboratory of the company SKB. The company operates for many years the underground laboratory Äspö, where long-term tests and experiments can be performed.

Technical and research reports of both these agencies are freely available (www.skb.se, www.posiva.fi)

NAGRA (Switzerland)

The Swiss agency NAGRA has long-term experience in the research and development of the geological repository. It made a number of experiments both in argillaceous formations (underground laboratory Mont Terri) and in the granite rocks (underground laboratory Grimsel - GTS). RAWRA signed a bilateral agreement with NAGRA that makes experiments in GTS possible. RAWRA participated on the experiment FEBEX II and at present it participates on the LTD (Long Term Diffusion) experiment. NAGRA research reports are available, a fee is charged (www.nagra.ch)

4 DGR SITE SELECTION

The concept of RW and SNF management in the Czech Republic stipulates to include two candidate sites into the land use plans until 2015. The working procedure (without taking the specific requirements of individual sites into consideration) was proposed and expertly assessed in the preceding years. In selecting the sites RAWRA proceeds in conformance with

the IAEA safety standard Siting of Geological Disposal Facilities, Safety Standards No. 111-G-4.1, 1004. For the site selection the requirement of stability for the respective time period and the absence of any mineable natural resources are from the point of view of safety of key importance. The geological environment should suitably protect the engineered barriers (container, buffer materials, backfill) and to provide for their long lifetime. Moreover, the geological barrier should minimize the transport of any radionuclide that could possibly be released from the system of engineered barriers into the environment. With respect to these requirements the geological environment should meet the following characteristics:

- The geological massif should be mechanically stable and the underground water flows should be low (a low hydraulic gradient)
- The underground water chemistry should be reducing, in an ideal case with neutral or slightly basic pH value
- The rock formation should exhibit good properties for the retardation of the radionuclides movement
- Transportation routes from the disposal system into the environment should provide a sufficient dilution and dispersion

The geological repository site is selected according to comprehensive technical criteria and requirements (the geological repository should provide the isolation function for a period of the order of 100 thousand years). In the case that a large number of sites will meet the safety and technological requirements also the non-technological criteria (e.g., the attitude of general public to the repository) could be applied in further narrowing of the number of sites. The basic criteria for the site selection from the point of view of nuclear safety are stipulated by the SÚJB Decree No. 215/1997 Coll. on Criteria for Siting Nuclear Facilities and Very Significant Ionising Radiation Sources.

In the connection with the termination of the step of the entire territory of the Czech Republic survey geological works in six relatively suitable sites started in 2003. Collection of more detailed geological data for the further narrowing of the sites number was the aim of these works. RAWRA managed and checked up the performed works with respect to the quality assurance program approved for these activities. The entire process of the site selection is divided into individual stages according to the character of the executed works and with respect to their connection to the respective legal standards. The basic characteristics of the individual stages are mentioned below. The works made since 2004 have been characterized as the geological survey (Act No. 62/1988 Coll. on geological works) and the area under survey had not to be approved. In 2005 the data acquired by aerial geophysical measurements were finished and the geological information system was completed by the data from the sites under survey. The research in the testing site Melechov pursued.

At present in all sites under survey the public mostly opposes the construction of the geological repository. Due to the mostly negative attitude of the public, RAWRA terminated all geological works in the sites until 2009. This time delay should provide for a space for searching mutually acceptable conditions between state and municipalities for continuation of the works. In May 2006 the Government of the Czech Republic approved by its Decree No. 561 the Regional Development Strategy of the Czech Republic. Sites, potentially suitable for the geological repository are part of this document in order to coordinate and launch the geological survey in these six sites with the objective to select two most suitable sites until 2015.

For fulfilling the objective of the sites selection the preparation of the basic materials for the geological works assignment (project of geological works, applications for the survey area approval, documents for the selective procedure) will commence in the next year.

Moreover, also the assessment of the environmental impacts of the geological repository in the given sites will start. A representative survey of the public opinion to the future building of GR in the sites will start as well.

Territory assessment stage

Works on the selection of suitable sites for the GR siting were made already since 1992. In 1992, with respect to the geological criteria, altogether 32 potentially suitable sites were selected by the Czech Geological Institute. Based on the requirement of the then Ministry of Economy and Industrial Development a broad team of experts was established under the leadership of the Institute of Nuclear Research Řež. This team narrowed down the number of 32 sites to 13 and, after a more detailed geological assessment, to 8 sites. The works were funded from the state budget and the results were approved by the respective commission of the Ministry of Environment. RAWRA proceeded in the previously performed works and in April 2003 completed the stage of the Czech territory survey using the comprehensively defined requirements in conformance with IAEA document Siting of Geological Disposal Facilities (SS No. 111-g-4.1). For selecting relatively more suitable sites for the next stage of works the nuclear safety and radiation protection requirements for the selection of a suitable geological environment, exhibiting an important long-term barrier of the repository, were preferred in compliance with the §4, Paragraph 3 of the Act No. 18/997 Coll. (the Atomic Act).

The assessment was made in the following steps:

Step 1: Exclusion of unsuitable sites

The most important and unchallengeable reasons for an extended site exclusion, affecting its safety and feasibility, were adopted as the first step of the GR site selection. These reasons can be found particularly among the external natural phenomena, excluding the GR siting. This assessment concerned first of all the tectonic structure of the area and its moving activities, the factor of seismic stresses, the factor of volcanic and postvolcanic activities.

Step 2: Selection of areas with propitious geological properties

DGR can be situated only in a suitable geological environment. The crucial property is the ability to isolate the disposed of radioactive materials from the surrounding environment for a long time period of 10^5 - 10^6 years. The suitability of the given rock formation is given by the mineralogical composition of the rocks, by their structure and texture, by the overall geological and tectonic structure, by the lithological sequence, by the descriptive and physical properties of the rock formation, by the hydrogeological structure of the site, and by morphology, not by the age of the rock formation. The basic requirements on the host environment parameters are specified in the SÚJB Decree No. 215/1997 Coll., §4, Paragraph a) and No. 307/2002 Coll., §52. The isolating and retention properties of the engineered barriers should be such that the inventory of the deposited radionuclides after their penetration through the barriers, including the rock formation, will not cause such a contamination of the respective components of the environment, that in any calendar year the average effective dose for the critical group of population will not exceed 250 μSv. In the second step of the selection procedure the regional geological parameters, structural and tectonic characteristics, and individual types of rock formations have particularly been assessed.

Step 3: Exclusion of regions due to the exclusion criteria

With respect to the nature of the deposited radioactive materials their isolation from biosphere for a period of the order of tens or even hundreds thousands of years is requisite. A multibarrier system, i.e., a combination of a natural barrier of the geological environment with several technical barriers, will be used to meet this requirement. The purpose of this step was to find from the regions selected from the point of view of propitious geological conditions areas suitable according to the criteria of the possible achievement of the long-term safety, feasibility of the construction, safe operation, and environment protection. Particularly, the following legal standards were used:

- SÚJB Decree No. 215/1997 Coll. on Criteria for Siting Nuclear Facilities and Very Significant Ionising Radiation Sources.
- Act No. 114/1992 Coll. on the nature and landscape protection

Step 4: Priority application

In this step the ranking of the site suitability for DGR will be determined, according to which the subsequent siting works will be performed. In the application of the generic principles of the nuclear facilities siting and conservative application of the safety case a low density of population was considered an advantage of the site. Under the assumption that urbanized areas are excluded for siting or are little suitable or unsuitable, water-covered areas are excluded, and agricultural areas should be assessed with respect to the type of cultivated crops, a partial preference was assigned to forested areas. A partial preference was assigned to agricultural areas where crops of direct consumption (fruits, vegetables, fodder) are not cultivated with respect to other agricultural areas, where technical crops are cultivated. Moreover, the possibility of the site connection to the transportation routes and the possibilities of supplying the necessary media were assessed as well as the expectable impacts to the environment and to the construction and operation economy.

Step 5: Evaluation

Based on the steps specified above the following six sites of relatively more suitable sites from the total eleven selected sites were chosen for the next stage of verification works.

Site No.	Site name	Region	Geologic formation
G/1	Lubenec-Blatno	Ústí nad Labem (Aussig)	Tisá section of the Čistec-Jesenice massif
G/2	Pačejov nádraží	Plzeňský (Pilsen)	Central Bohemian pluton - type Blatná
G/3	Božejovice-Vlksice	South Bohemia	Central Bohemian pluton - Devil's Burden
G/4	Pluhův Žďár –Lodhéřov	South Bohemia	Klenová massif
G/5	Rohozná	Highlands	Moldanubian pluton
G/6	Budišov	Highlands	Třebíč-Meziříčí massif

Stage of the sites number narrowing (2003 - 2005)

At this stage the geological works were performed in conformance with the project "Survey of the selected granitoidic massifs homogeneity - Project of works on a hypothetic site (Skopový J. et al. 1999)" - pre-realization stage of the works. In particular, they comprised updating of the archive search for geological information on the selected sites, establishing geographical information systems for the individual sites, performing aerial and in a limited extent also ground geophysical measurements, evaluation of the satellite and aerial optical and radar photographs, terrain reconnaissance and identification of land owners. All this concerned works that did not require entry on the land estates.

Technical works, including terrain reconnaissance, were completed in 2004. In 2005 the activities were focused namely on the interpretation of the obtained results and on the preparation and elaboration of summary reports. Simultaneously, the works on the geographical information system were also completed. The summary reports on the project, in total about 1300 pages of text with a number of graphical supplements were peer reviewed by four independent opponents in the first half of December 2005. The works resulted in narrowing the areas of the individual sites and in a proposal of the future survey areas delimitation.

A preliminary feasibility study has been worked out for each of the proposed sites, comprising and interpreting all information available at this stage of the works on the problem. Due to the lack of data on the deep parts of the massifs the preliminary study dealt only with the possibility to situate the surface premises, with their linkup to the transportation networks and infrastructure, with the conflicts of interest, risks analysis, and with the partial comparison of the economic demands. For future works in all sites under scrutiny it is of basic importance that the study confirms the possibility to situate the surface premises in all sites.

Full texts of the summary reports and feasibility studies are available on the www.surao.cz website.

Stage of the site characterization (2009 - 2015)

Geological works of this stage will be made in the approved survey areas. In order to meet the objectives of the Concept of RAW and SNF Management it is necessary to verify minimum two sites. The works will be suitably optimized. In the past a document "Survey of the selected granitoidic massifs homogeneity - Project of works on a hypothetic site (Skopový J. et al. 1999)" has been worked out for this stage of the project. This document will be updated.

In the so-called reconnaissance stage the proposed geological works encompass works as follows: verification of the granitoidic body depth reach, long-distance survey of the Earth, geological mapping, large-area geophysical survey, shallow drills (punctures), large-area geochemistry, equipment for the hydrological monitoring network, monitoring of material flows and critical stresses in a small watershed, hydrogeological monitoring, engineering-and-geological mapping, and basic geotechnical characteristics of the surface parts of the rock massif, interpretative geophysical profiles, geochemical details. In the stage of implementation the following works are anticipated: digging, drilling, logging, detailed geophysical survey, structural petrological analysis, petrographical and mineralogical works, pursuing of the hydrological monitoring and of the material flows monitoring, hydrogeology, geochemistry, engineering geology, and geotechnology. From this spectrum of works those

will be chosen for the period 2009-2015 that will bring forth the most pertinent information for the determination of the respective protected area, the other works will be gradually finished after 2015.

Inclusion of the candidate sites into the land use plan (2015)

In sites evaluated by the geological survey as sites suitable for the DGR siting and suitably meeting also other requirements it is necessary to provide for the limitation of their uncontrolled exploitation and execution of uncontrolled technological, particularly drilling works. Declaration of a protected area for a special interference into the Earth crust according to the Act No. 44/1988 Coll. (Mining Act) as amended, serves to this purpose. The decision on the declaration of a protected area for a special interference into the Earth crust means to include the site into the land use plan (territorial plan). The declaration of the protected area is expected in two sites that will be characterized in conformance with the project of geological works and that will also suitably meet even other requirements.

5 DESIGN ACTIVITIES AND DEVELOPMENT OF THE DISPOSAL SYSTEM

At present the concept of the multibarrier system represents the backbone of the geological repository plans in most countries. In this system the individual barriers have mutually complementing safety functions in order to balance out the unavoidable uncertainty in long term behaviour. The safety barriers are not fully independent. The disposal system consists of components that act in mutual interaction.

There is a considerable flexibility in the combination of individual components of the engineered barriers system with the host rock formation so that the safety case can be fulfilled. Due to different amounts and nature of radioactive waste in various states and due to the different geological conditions a number of concepts of repository systems have been worked out that achieve similar operational parameters - however, with a different accent to the role of individual barriers.

The multibarrier system and its functioning are described in the Reference Design. After finding and verifying the final site, the design of the engineered barriers will be tailored with respect to the safety and economic indicators that will take into consideration the geological conditions of the given site.

The safety case puts usually a higher emphasis on the near field interactions (engineered barriers and the delimitated zone of the surrounding environment). The safety analyses published in Sweden (SR 97), Finland (TILA 99), and Switzerland (Nagra, 2002) also put an accent to the behaviour of the near field interactions for securing the disposal system safety.

It is improbable that the geological repository environment will be affected by the climatic changes and by the human activities on the surface. Moreover, the sites are chosen so that there are no natural resources in the vicinity so that the probability of a future intrusion of humankind into the repository is rather low. The execution of engineered barriers will be affected by the geological environment, in which the repository will be situated. The engineered barriers comprise the matrix of the spent nuclear fuel, container, buffer and backfill materials. The buffer and backfill materials with very low permeability are chosen so

that they can effectively prevent any advective flows in the barriers. Under reducing conditions the corrosion rate should be low which effectively prevents any contacts of the spent fuel with water, in particular in the initial stages when the radioactivity of the spent fuel is still high.

Finally, when the disposal container will be degraded and the underground water will come into contact with the spent fuel matrix, the release rate of radionuclides will be extremely slow due to the low solubility of the spent fuel matrix. Moreover, the reducing conditions limit the solubility of many radionuclides.

In the buffer material (bentonite) the radionuclides released from the spent fuel matrix will migrate by the diffusion process. Bentonite and the backfill material exhibit also the filtration function, hindering the migration of colloids. In the rock formations surrounding the engineered barriers the transport of radionuclides is governed by a slow flow of the underground water and by the interaction with the rock materials. During the migration with underground water the nuclides will be dispersed and gradually diluted. Moreover, the long transportation times in combination with the radioactive decay will decrease their concentration.

The repository project should be adequate from the economic point of view and should use the available technology. The manufacturing, construction and assembly works should be performed according to the pre-specified quality requirements.

SNF/HLW Matrix

For an appropriate design of the disposal system it is necessary to know the detailed characteristics of the disposed off SNF and HLW, particularly their leachability. Studies of SNF corrosion and of the matrix leachability proceed worldwide for many years and many research reports are available. RAWRA assumes to make only a survey of published research results in this field and to use up the available, namely foreign data.

Container

The role of the disposal container is crucial for ensuring the long-term safety of the repository. A number of requirements are posed on the container, in particular:

- long-term impermeability
- resistance against the chemical environment in the repository
- resistance against the external pressure

In the container design works RAWRA could make use either of the Swedish/Finnish container (double-wall container with copper envelope) or of the Japanese steel thick-walled container. Both these concepts will be permanently followed. The final solution will be decided by the future properties of the site and by the required safety margin. RAWRA will use the available foreign and domestic information (e.g., the design information of SKB, NUMO, or the results of the 5th general plan CONTAINER CORROSION project) as the basic materials for the project design process.

Sealing materials (bentonite, buffer)

The choice of the proper sealing material (buffer) has a great importance for the disposal system correct functioning. A number of requirements are also posed on the sealing material, in particular it has to:

- completely seal and protect the container over a long time,
- prevent any access of underground water to the container,
- facilitate a good heat transfer from the container,
- be chemically stable.

In all designs of the disposal system a material on the basis of bentonite is proposed. Bentonite is a material containing predominantly argillaceous minerals from the group of smectites. The ability to absorb water and to swell is their typical property, which means formation of sealing properties. In the Swedish project the use of bentonite from Wyoming (U. S. A.) is assumed. Also bentonites from Denmark and Norway were studied.

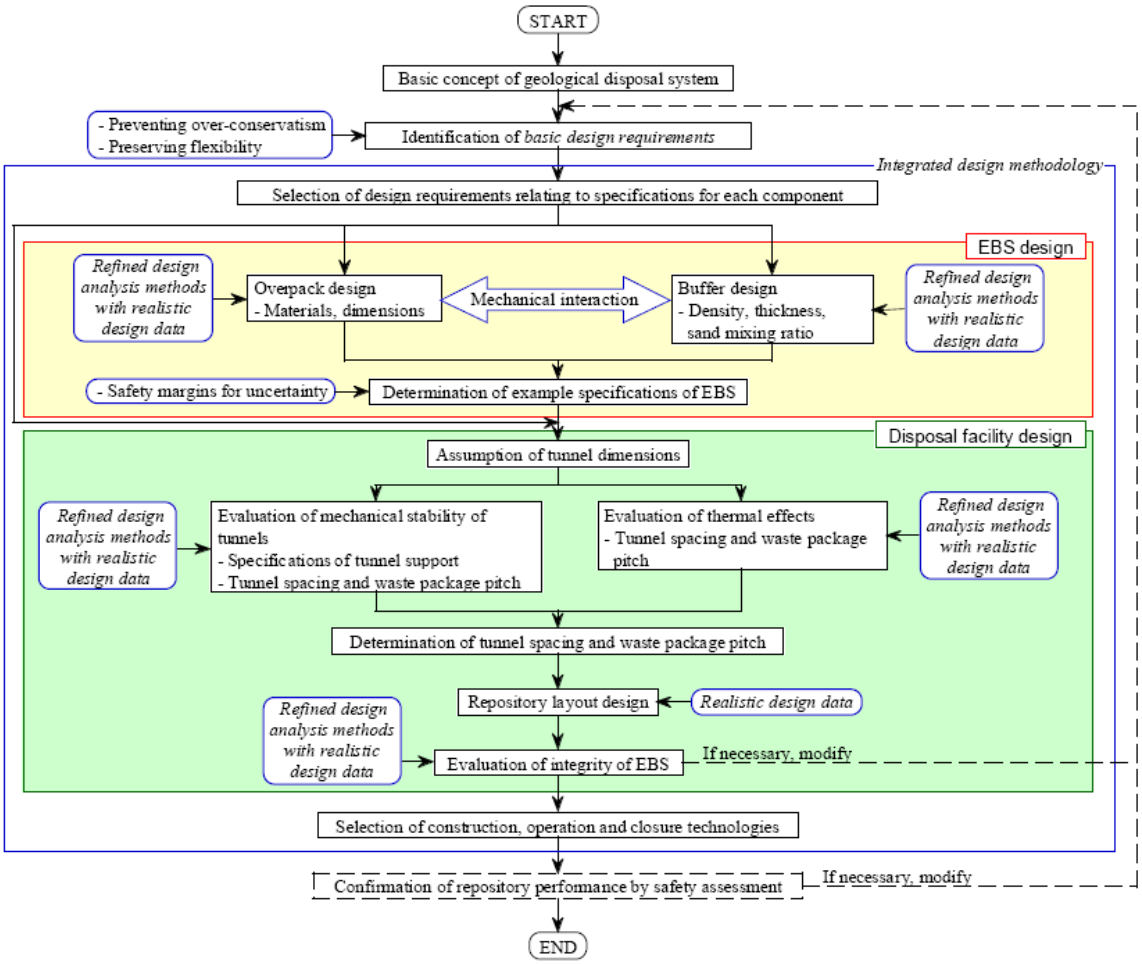
RAWRA will pursue the possibility of using bentonites of domestic origin. The tests and experiments (performed by the Centre of Experimental Geotechnics of the Czech Technical University) will be pursued with the aim to obtain comprehensive characteristics of Czech bentonites.

The design of the disposal system

The basic design of the repository is given in the Reference Design (1999). The design has been worked out on the basis of knowledge of the nineties with respect to the design depth. RAWRA is planning to prepare an updated version of the Reference Design together with the comprehensive safety assessment so that the international state of the art will be used in a more extent measure. At the time of the Reference Design updating the results of the 6th general plan projects will be available, in particular:

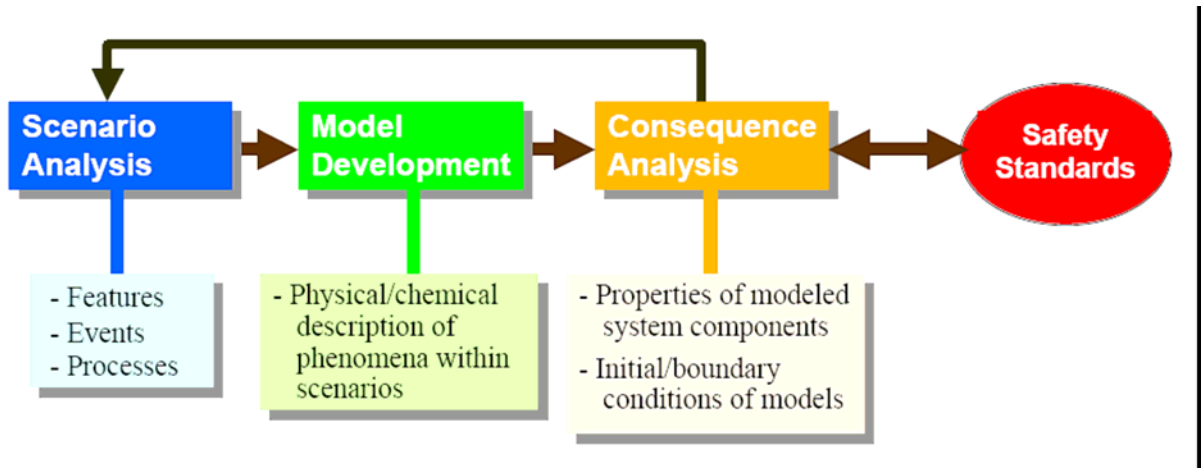
- NF-PRO (near field behaviour assessment)
- FUNMIG (far field behaviour assessment)
- ESDRED (assessment of technologies)
- PAMINA (safety analyses methodology)

The design solution will take into consideration the needs of the Czech nuclear power production and will take into account both the prolongation of the existing NPP operation and the generation of SNF from new nuclear reactor units. It will also take into consideration the disposal of HLW from the possible reprocessing of SNF. The project process will proceed by an integrated procedure as illustrated by the diagram given below:



6 SAFETY ASSESSMENT OF THE DISPOSAL SYSTEM

For the assessment of the host rock suitability and of the repository design it is necessary to apply a systematic and transparent method for the safety assessment that will make possible to assess the safety and to make a comparison with the safety limits. The geological repository safety system assessment differs from that of the other engineering system by the fact that an extremely long time period should be taken into account and that a natural environment that is rather variable and covers a rather large area should be assessed. It is therefore not possible to apply common engineering procedures in which the entire system is constructed and operated so that its own safety is evident. This is a specific issue of the safety assessment of the geological disposal. The general methodology applied for the safety assessment has been developed and is illustrated in the diagram below:



In the first instance, the scenarios of the possible future behaviour of the disposal system are elaborated, based on the assessment of the disposal system characteristics and various effects and processes that may affect their change in time. Further, models are worked out so that they may represent the development of the system and subsequently they are used for the forecast analysis of the system behaviour.

In order to assess the system safety case the results are compared with the respective limits. Nevertheless, it is necessary to reasonably assess whether something had not been omitted in all potential scenarios or whether it had not been taken into account twice and whether the individual evaluation instruments are fully verified and models and data for the assessment adequately validated.

The aim of the program of the safety assessment is to determine the geological repository safety concept based on the safety case analysis. The research will be orientated so that it will be possible to fulfil the SÚJB document form "Procedure of the elaboration of the preliminary safety report for the radioactive waste repository construction permit" of November 2003. For this purpose all the available data on the engineered and natural barrier system, obtained from the programs of the near and far field research, from the proposed design, from the studies of analogues, and from the respective domestic and foreign sources will be used.

Program of the works is divided into four main topics:

- provision of technical means for the safety assessment (data, methods, computational assessment software and hardware),
- working out of the procedure of reasoning, analyses, and arguments for the safety assessment,
- synthesis of the proofs, arguments, and analyses, sensitivity analysis, and uncertainty analysis,
- examination of variants and recommendation of the geological repository safety case.

Defining the uncertainties that could result in the underestimation of processes affecting the repository safety is an important outcome of the safety analyses. Some uncertainties will be eliminated or reduced. Simultaneously, the results of the parallel research

and development studies will be used as, e.g., the geological survey and research, design studies, demonstration tests in laboratory scale, or in situ measurements of the migration parameters and substantiation of the safety analysis conditions from a higher number of points of view, e.g., from the natural analogues studies or from the observations of the used materials durability.

For the determination of the repository safety functioning within the framework of the proposed safety case the repository basic safety functions will be assessed both qualitatively and quantitatively:

- isolation of radionuclides from their immediate surrounding, from water in particular, by the sealing, provided by the engineered barriers, limitation of flows, provided by the natural barrier, and also by the capacity of some engineered barriers for retarding the entry of radionuclides into the biosphere.
- retardation and dispersion of the radionuclides release, provided by the restriction of leaching, diffusion and retention: the system hinders the movement of radionuclides that were released from the matrix,
- dilution and dispersion on the geological environment/biosphere interface.

7 RELATED RESEARCH AND DEVELOPMENT

Research and development related to the disposal of radioactive waste comprises namely the so-called advanced methods of SNF processing that should substantially decrease the amounts of long-lived radionuclides in the disposed of waste. These technologies, provided that they will end in the stage of commercial use, could mitigate the requirements posed upon the DGR (on its capacity and particularly on the period of time for which the repository should be isolated), nevertheless they will not remove the necessity to build the DGR. The Concept of RAW and SNF Management, approved by the Government, stipulates to monitor the development of the advanced technologies. Of these, the transmutation technology is particularly important. By transmutation we understand the conversion of long-lived nuclides into nuclides either stable or short-lived, using neutrons in a reactor, i.e., exploiting the same nuclear reactions that are already proceeding in nuclear reactors. Very often charged particles, accelerated in the accelerators and producing sufficient amounts of neutrons in a reaction with a suitable target, are considered a suitable source of neutrons. Development of a new generation of reactors proceeds worldwide that would be able to exploit the fuel more effectively than the existing reactors. It is therefore probable that transmutation will be limited only to the SNF from the existing reactors.

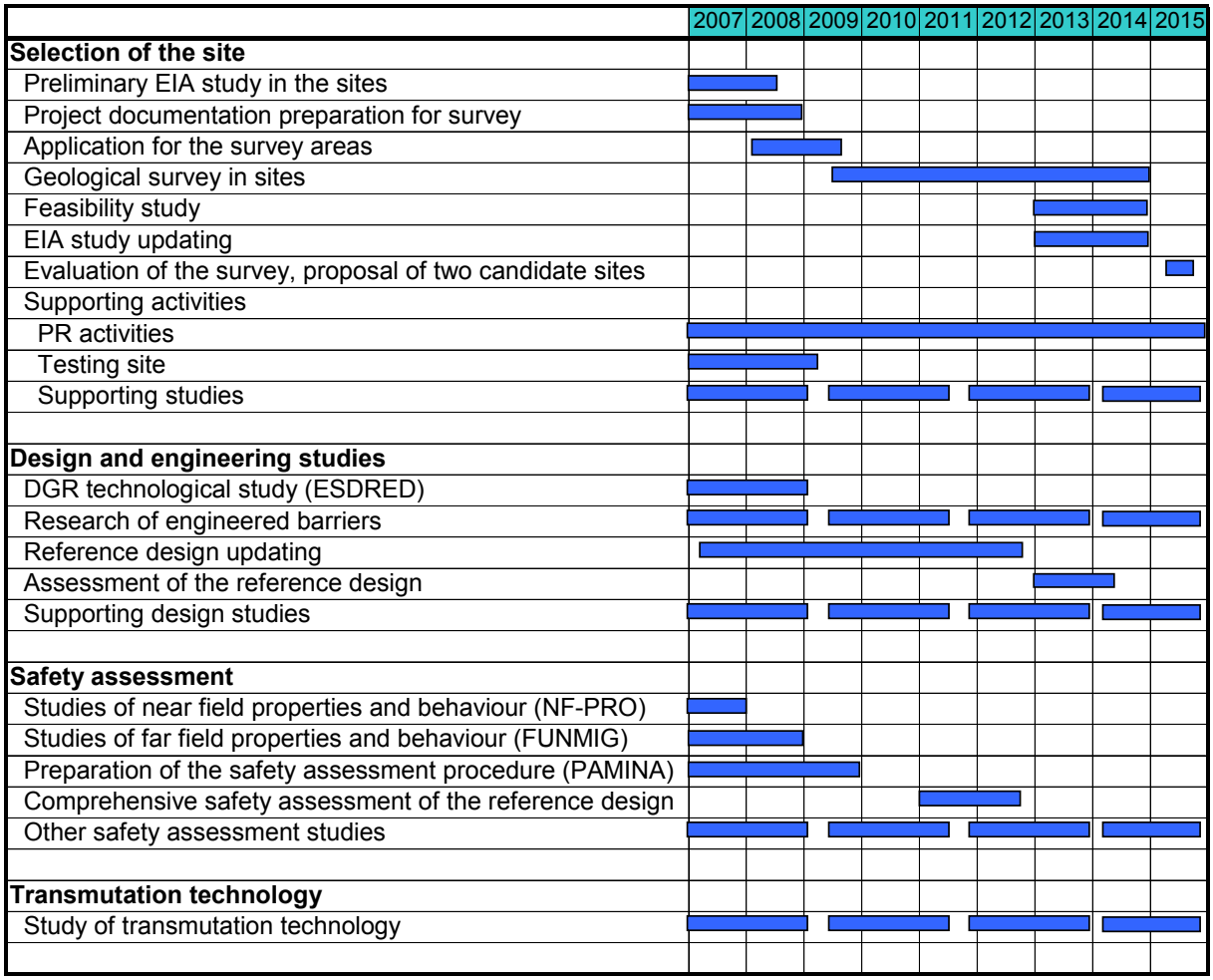
Technological processes connected with transmutation are too complicated for the Czech Republic to develop the entire chain of components. It is therefore very important to integrate the Czech Republic into the international cooperation. At present the integration into the EU and GIF (Generation IV International Forum) activities is the most imperative. The Czech Republic, as a Member State of EU, is involved in the development (e.g., of the molten salt reactor as one of the six reactor types under development).

Transmutation is achieved in transuranium elements by the nuclear fission process, in other nuclides by the neutron capture. For transmutation to fulfil its purpose it is necessary to separate uranium and plutonium from the fuel and to separate the minor actinides (Np, Am, Cm). These processes are denoted by the term "partitioning".

In the Czech Republic the research is focused to two main topics: 1) partitioning, and 2) transmutation in reactors with molten fuel on the basis of fluorides at high temperatures. The research of partitioning is a part of international projects and follows both the aqueous process, i.e., the improvement and extension of the existing technologies of the spent fuel reprocessing, and the pyrochemical methods leading to the separation of fluoride (halogenide) compounds at high temperatures. Recently, in the field of transmutations, the research is limited to an option without external neutron source (i.e., critical reactors) and it is orientated to the SPHINX concept. According to this concept the fuel is dissolved in a carrier melt and circulates in the active zone.

8 TIME SCHEDULE UNTIL 2015

An overall time schedule of the principal research and development works is presented in the table below.



9 BUDGET UNTIL 2015

The following table presents the assumed budget of research and development works until 2015 at the price level of 2006, in million CZK.

	2007	2008	2009	2010	2011	2012	2013	2014	2015
Selection of the site									
Preliminary EIA study in the sites	2	2							
Test site	2	2	1						
Geological survey in three sites			10	15	37	38	38	33	6
EIA study updating							3	2	
Design and engineering studies									
Research of engineered barriers	7	7	8	8	8	8	9	9	9
Reference design updating	1	2	2	2	1				
Supporting design studies	3	3	3	4	4	4	5	5	5
Safety assessment									
Studies of near field properties	9	6	6	3	3	4	4	4	5
Studies of far field properties	3	3	3	2	2	3	3	4	4
Safety assessment of the reference design	1	2	2	2	2	1	1	1	2
Other safety assessment studies	1	2	1	2	1	2	2	2	2
Transmutation technology									
Study of transmutation technology	9	9	9	10	10	10	11	11	11
Total	38	38	45	48	68	70	76	71	44

10 LONG-TERM OUTLOOK

The following objectives have been specified for the checkup of the fulfilment of intentions stipulated by the Concept of RAW and SNF Management in the field of the geological repository development:

To prove the suitability of one site for the geological repository siting based on the execution of the respective geological works and assessment of results	2025
To prepare all design and supporting documentation for the onset of the underground laboratory construction and performance of long-term experiments for proving and confirmation of the geological repository safety	2030
Commissioning of the geological repository	2065

General survey of works anticipated for the fulfilment of the milestones mentioned above is presented below:

Period 2015-2025

After 2015 one main and one reserve site for GR should be approved. The works in this period will characterize the selected (main) site in more details. The executed geological works will comprise both geophysical and drilling methods. For proposing the extent and composition of works the foreign experience, e.g., from the geological works made for the characterization of the Olkiluoto site, could be used. There is enough time for planning and execution of the geological works. On the basis of more detailed characterization of the site it will be possible to design the underground layout of the repository and to prepare the respective mining design documentation for the beginning of the underground laboratory excavation.

In the field of the design and research works further updating of the Reference Project is anticipated. New, more precise data on the behaviour of individual engineered barriers should be available as well as better understanding of the underground water geochemistry in the repository site. Furthermore, data from the excavation of the geological repositories in Sweden and Finland should be available, the onset of operation of which is expected shortly after 2020.

In the supplementary research we expect new works in the field of the transmutation technologies, based on the international cooperation.

Period 2025-2030

According to the Concept of RAW and SNF Management all designing and supporting documentation for the beginning of the underground laboratory construction should be prepared in this time period. The onset of the underground laboratory construction is expected after 2030. With respect to the international experience the importance and necessity of verifying materials and technologies in an underground laboratory will decrease. Information from the construction and operation of repositories in Sweden and Finland, including the operational technologies used, should be available. It could be expected that the beginning of the underground laboratory excavation will be postponed in time, even by as much as 20 years, i.e., approximately to the year 2050. We base this estimation, e.g., on the experience from the situation in Finland, where - due to the long-term testing of the repository system components in the Swedish underground laboratory Äspö - the Finnish firm POSIVA started the construction of its own underground laboratory Onkalo about 15 years before the assumed repository operation onset.

Period 2030-2065

Excavation of the underground laboratory and subsequently of the first segments of the geological repository should start in this time period. After 2050 also the construction of the surface premises of the geological repository should start, including also the SNF encapsulation plant. Information from Gorleben, Germany, is available already today (fully

constructed surface area, including also the SNF encapsulation plant), also information from Sweden, Finland, Switzerland, Japan, and evidently also from other countries should be also available. The assumed schedule of construction works is elaborated in the Reference Project. The repository should be prepared to accept SNF since 2065. The Concept of RAW and SNF Management provides a sufficient time for the fulfilment of this milestone.

REFERENCES

[1] Koncepce nakládání s radioaktivními odpady a vyhořelým jaderným palivem (Concept of radioactive waste and spent nuclear fuel management), Government Decree No. 487 of 15 May 2002, cf. also www.surao.cz

[2] Act No. 18/1997 Coll., on the peaceful use of nuclear energy and ionizing radiation (Atomic Act), SÚJB Decree No. 215/1997 Coll., on the criteria for siting nuclear facilities, Act No. 44/1998 Coll., on the protection and exploitation of mineral resources (Mining Act), Act No. 62/1988 Coll., on geological works, Act No. 114/1992 Coll., on the protection of nature and landscape, Act No. 254/2001 Coll., on waters (Water Act), Act No. 164/2001 Coll., on the natural curative springs, Act No. 13/1997 Coll., on surface transport routes, Act No. 266/1994 Coll., on railways, Act No. 50/1976 (183/2006) Coll., on territorial planning and building activities (Construction Act), etc.

[3] SÚJB Decree No. 307/2002 Coll., on radiation protection

[4] SÚJB Decree No. 215/1997 Coll., on Criteria for Siting Nuclear Facilities and Very Significant Ionising Radiation Sources

[5] The Principles of Radioactive Waste Management, IAEA SS No. 111 - F, Vienna, 1995

[6] Classification of Radioactive Waste, IAEA SS No. 111-G-1.1, Vienna, 1994

[7] Scientific and Technical Basis for the Geological Disposal of Radioactive Wastes, IAEA TRS No. 413, Vienna, 2003

[8] Siting of Geological Disposal Facilities, IAEA SS No. 111-G-4.1, Vienna, 1994

[9] Geological Disposal of Radioactive Waste, IAEA SS. No. WS-R-4, Vienna, 2006

[10] Implications of Partitioning and Transmutation in Radioactive Waste Management, IAEA, TRS No. 435, Vienna, 2004

[11] RD&D – Programme 98, SKB, 1998

[12] RD&D – Programme 2004, SKB, TR-04-21, 2004

[13] Programme for Research, Development and Technical Design for 2004 – 2006, POSIVA, 2003

[14] H12 : Project to Establish the Scientific and Technical Basis for HLW Disposal in Japan, JNC, 2000

[15] Project Opalinus Clay, Safety Report, Nagra, 2002

[16] SR 97 – Post Closure Safety, SKB, TR – 99-06, 1999

[17] Projects of the 5th and 6th general plan EU EURATOM, www.cordis.europa.eu/fp6-euratom