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Interim FEP report for the safety assessment SR-Can

Svensk Kärnbränslehantering AB

August 2004

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Preface

This report describes the FEP processing done for the interim stage of the SR-Can project and the resulting interim version of the SR-Can FEP database. The report is authored by Kristina Skagius, Kemakta Konsult AB. She has also developed the structure of the FEP database and carried out all the practical FEP implementations and mappings in the database.

The work described in the report was planned by a group consisting of Kristina Skagius, Johan Andersson, JA Streamflow AB, and the undersigned. Many of the decisions regarding FEP classification etc were made by this group as is further explained in the report.

Several other experts and generalists have been involved at specific stages of the work, including Lena Morén, SKB (issues related to climate and future human actions), Ulrik Kautsky, SKB (biosphere issues), Karin Pers, Kemakta Konsult AB (issues related to the initial state) and Patrik Sellin, SKB, together with Ola Karnland and Lennart Börgesson, Clay Technology AB (issues related to buffer processes).

Stockholm, August 2004

Allan Hedin
Project leader, SR-Can

Summary

This report describes the work with identification and structuring of features, events and processes (FEPs) that has been carried out within the scope of the SR-Can safety assessment up to the time of the interim reporting of the project. The overall objective of the work is to develop a database of features, events and processes in a format that would facilitate both a systematic analysis of FEPs and documentation of the FEP analysis as well as facilitate revisions and updates to be made in connection with new safety assessments. This overall objective also includes the development of procedures for a systematic FEP analysis as well as to apply these procedures in order to arrive at an SR-Can version of the FEP database.

The work started by implementing the content of the SR 97 Process report into a database format suitable for import and processing of FEP information from other sources. The SR 97 version of the database was systematically audited against the NEA database with Project FEPs, version 1.2. In addition, an earlier audit of the SR 97 process report against the interaction matrices developed for a deep repository of the KBS-3 type was revisited and updated.

Relevant FEPs from the audit were sorted into three main categories in the SR-Can database i) FEPs related to the initial states of the repository system, ii) FEPs related to internal processes of the repository system, and iii) FEPs related to external impacts on the repository system. These groups of FEPs were further processed for making decisions on how to handle these FEPs in the assessment. Biosphere processes were not included in the SR 97 Process report and there is thus not the same basis for updating these descriptions as for the engineered barriers and the geosphere. All biosphere FEPs from the audit have therefore been compiled in a single category in the database, but remain to be further handled. FEPs were also categorised as irrelevant or as being related to methodology on a general level. This latter group of FEPs is also documented in the SR-Can version of the FEP database.

The further processing of the initial state FEPs revealed that those FEPs that are not covered by the description of the repository design or by the site description, concern deviations from the intended initial state as a consequence of undetected mishaps, sabotage etc. These FEPs were propagated to the selection of scenarios. Relevant process FEPs from the audit were used to update the SR 97 set of internal processes for the engineered barrier system and the geosphere. The resulting SR-Can set of processes for the buffer are documented in the interim version of the SR-Can Process report and as process headings in the SR-Can interim version of the FEP database. Preliminary lists with SR-Can processes for the other system components are presently available in the interim version of the FEP database, but these lists will be further processed and documented in the final version of the SR-Can Process report. External FEPs from the audit were checked against the plans for managing these issues in SR-Can. Climate and large-scale geological FEPs were compared against the plans for modelling these phenomena and the handling of future human actions were compared to the handling in SR 97, which forms the basis for the handling in SR-Can. The coverage was found satisfactory. The results are not documented in the interim version of the SR-Can database, but will be so in the final version of the SR-Can database.

Contents

1 Introduction

1.1 Background

The methodology adopted in SKB's most recent safety assessment of a deep repository for spent fuel, SR 97 /SKB, 1999a/, included the development of process descriptions and process diagrams as a part of a qualitative description of the possible future evolution of the repository system. As a result of this work the need for a more systematic and comprehensive examination of the physical components and processes of the repository system was identified.

In order to meet this demand, it was decided to further develop SKB's database of features, events and processes (FEPs) relevant to long-term safety of a nuclear waste repository. The work was initiated during the preparatory phase of the safety assessment SR-Can and part of the results were entered into the planning report for SR-Can /SKB, 2003/.

1.2 Scope and objective

The overall objective of the work is to develop a database of features, events and processes in a format that would facilitate both a systematic analysis of FEPs and documentation of the FEP analysis as well as facilitate revisions and updates to be made in connection with new safety assessments. This overall objective also includes the development of procedures for a systematic FEP analysis as well as to apply these procedures in order to arrive at an SR-Can version of the FEP database.

To meet this overall objective, the following more specific demands on the database were defined:

- The database shall contain descriptions of internal processes in the repository system as well as of system variables, initial state and external factors.
- The database structure shall allow for documentation of expert judgements of the importance of interactions between internal processes and system variables as well as for automatic generation of diagrams displaying these interactions (process diagrams in SR 97 Process report /SKB, 1999b/), if possible.
- The database shall facilitate a systematic audit against NEA's database with Project FEPs and possibly also audit against other potential FEP sources as well as display the results of the audit.
- It should be possible to generate new versions of the database and save old versions without large modifications in the database structure. In addition, it is beneficial if the contents of the database can be transferred to a report of similar structure as the SR 97 "Process report" with a minimum of editorial work.
- The development of the SKB FEP database should start with implementing the SR 97 Process report as the first version of the database named Version SR 97.

This report describes the achievements and results of the work with the development of the FEP database that are available for the interim reporting of the SR-Can project and how the FEP database has been utilised for a systematic analysis of FEPs. The work will continue and finally be reported when the database for SR-Can is completed.

1.3 Experts used in developing the FEP database

The details of the FEP database development procedure were decided at meetings held at regular intervals during the course of the work. Participants in these meetings were Allan Hedin, SKB, Johan Andersson, JA Streamflow AB, and Kristina Skagius, Kemakta Konsult AB, in the forthcoming text referred to as the FEP group. This group also made decisions regarding the treatment of FEPs during the audit stage and participated in the further processing of the outcome of the audit. Karin Pers, Kemakta Konsult AB, and Lena Morén, SKB, participated in the work with the processing of the lists of FEPs related to initial states and external factors. Allan Hedin, SKB, Patrik Sellin, SKB, Ola Karnland ClayTech and Lennart Börgesson, ClayTech are the main persons involved in the implementation of the audit results concerning buffer processes.

1.4 This report

In Chapter 2, the procedures applied in arriving at the SR-Can version of the FEP database are described and results of the different steps are exemplified. The status of the FEP analysis work at the time of the interim reporting of SR-Can is summarised in Chapter 3. The structure and content of the SKB FEP database at the time of the interim reporting of the SR-Can assessment is described in Chapter 4 with the purpose to give guidance as to how to get access to the different types of information that are collected in the digital version of the database.

2 FEP analysis procedures and results

2.1 Overview

Three sources were used to identify relevant features, events and processes influencing the long-term safety of a KBS-3 type repository. These are the SR 97 Process report /SKB, 1999b/, the international NEA database with project FEPs version 1.2 /NEA, 1999/ and the Interaction matrices developed for a deep repository of the KBS-3 type /Pers et al, 1999/. The procedure followed is schematically illustrated in Figure 3-1 in Chapter 3.

The work started by implementing the content of the SR 97 Process report into a database format suitable for import and processing of FEP information from other sources. This first version of the database is denoted version SR 97 and it contains descriptions of the components of the repository system, system variables definitions and process descriptions, all in accordance with the SR 97 Process report.

In the next step, the SR 97 version was systematically audited against the NEA database with Project FEPs, version 1.2. In addition, the earlier audit of the SR 97 process report against the interaction matrices developed for a deep repository of the KBS-3 type /Pers et al, 1999/ was revisited and updated. The purpose of these audits was to identify processes that should be added to the SR 97 list of processes and to compile lists of external factors and deviations in initial states that could be used as a basis for a systematic selection of scenarios for the future evolution of the repository system. In addition, the audit resulted in a compilation of initial states FEPs of the system components that need to be taken into account.

The outcome of the audit was further processed in somewhat different ways. Suggestions regarding additions and modifications of internal processes arising from the audit were and will be treated by the experts involved in the development of the Process report for SR-Can. At the time of the interim reporting of SR-Can, this part of the work has been carried through for the buffer processes and the result is an updated version of process descriptions for the buffer system /SKB, 2004a/.

The produced lists of initial states, deviations in initial states and external factors were processed in order to specify how all identified relevant factors are or will be handled in an appropriate and motivated manner in the safety assessment SR-Can.

The development procedure and the results are described in the following subsections. The status of the work and the structure and content of the FEP database version SR-Can at the time of the interim reporting of the SR-Can project are described in the following Chapters.

2.2 System definition

The SR-Can FEP database is devised for the KBS-3H repository system. To be able to distinguish between FEPs belonging to the repository system and FEPs acting outside the system, a definition of the system boundary is necessary. Furthermore, in the database, this system is divided into several system components. It should be noted that these definitions primarily were set up to facilitate the auditing procedure and the development of the SR-Can version of the database. Therefore, all these definitions are not necessarily relevant in subsequent treatments of FEPs in the safety assessment, e.g. through modelling.

2.2.1 System boundary

To be able to distinguish between FEPs belonging to the repository system and FEPs acting outside the system, the following definitions related to the system boundary were made:

- Roughly the portion of the biosphere studied in site investigations, e.g. an area of the order of 100 km^2 above the repository, is regarded as internal, whereas the biosphere on a larger scale is regarded as external.
- Local effects of climate are internal, but not the climate system on a larger scale.
- Roughly the corresponding portion of the geosphere down to a depth of about 1000 m is regarded as part of the system. Depending on the analysis context, this definition may also be somewhat modified.
- Future human behaviour on a local scale is internal to the system, but not issues related to the characteristics and behaviour of future society at large.

It was also noted that, in general, a strict boundary definition is neither possible nor necessary, and the same boundaries will not necessarily be relevant to all parts of the safety assessment.

In order to distinguish between factors affecting the initial state of the repository system and factors being part of the evolution of the system, the initial point in time for the evolution of engineered barriers was defined as the time of deposition. The initial state of the geosphere and the biosphere was defined as that of the natural system prior to excavation and construction of the repository. This means that the evolution of the natural conditions at the site as a result of construction belongs to the system description. The definition of the point in time for initial state is further discussed in the Interim main report (Chapter 3) /SKB, 2004c/.

2.2.2 System components

The repository system encompasses the spent nuclear fuel, the canisters, the buffer, the tunnel backfill, the geosphere and the biosphere in the proximity of the repository. In the SR 97 Process report /SKB, 1999b/, the buffer and tunnel backfill were treated as one system component and the biosphere was not included. When starting the development of the SR-Can version of the FEP database it was decided that the buffer and the tunnel backfill should be treated as two separate system components and that the biosphere system should be added.

During the audit work, it was further found convenient to increase the resolution in the definition of system components outside the buffer in order to obtain system components that are homogeneous in character and to make it possible to distinguish between system components that are more important to safety and those that are less important. However, the geometrical extent and materials included in the system components “Fuel/cavity in canister” and “Cast iron insert and copper canister” remain the same as in the SR 97 version.

After these modifications, the system description and the SR-Can database included the following system components:

- *Fuel/cavity in canister*. This system component comprises the fuel assemblies with fuel pellets, cladding tubes, channel, handle, and spacers etc, as well cavities in the canister that could become filled with water in case of a canister rupture.

- *Cast iron insert and copper canister.* This system component comprises the canister with its inner container of cast iron and outer shell of copper.
- *Buffer.* This system component comprises the buffer of bentonite clay that surrounds the canister in the deposition hole.
- *Bottom plate in deposition hole*. This system component comprises the concrete foundation in the bottom of the deposition holes and the copper plate on top of the concrete on which the buffer resides.
- *Backfill in deposition tunnels.* This system component comprises the material that will be emplaced in the deposition tunnels after deposition of the canisters and buffer in the deposition holes. In the interim reporting of SR-Can, this system component also includes rock bolts and reinforcement nets that will be used as rock support as well as grout in the grout holes. These grout holes are used for grouting of the rock around the deposition tunnels during excavation and will be left grout-filled at repository closure. In order to obtain a more homogeneous system component, rock reinforcements and grout will most likely be considered as a separate system component in the coming analyses to be reported in SR-Can.
- *Backfill in other repository cavities.* This system component comprises the material that will be emplaced in all other repository cavities except the deposition tunnels and deposition holes, e.g. the ramp, transport and main tunnels and shafts. In SR-Can it is assumed that this material is the same as the backfill material in the deposition tunnels. Similarly to the system component backfill in deposition tunnels, this system component presently also includes rock reinforcement and grout in grout holes, which most likely will be separated into a system component of its own or possibly combined with rock reinforcement and grout in the deposition tunnels in the final reporting of SR-Can.
- *Plugs.* This system component comprises all operating seals or plugs in the repository that are left at closure as well as all potential permanent plugs that will be installed for long-term safety reasons, e.g. plugs between deposition areas.
- *Borehole seals.* This system component comprises the backfill materials in all boreholes drilled for site characterisation during the surface-based site investigations as well as during repository excavation and construction. The backfill materials considered in SR-Can is highly compacted smectite clay contained in perforated copper tubes, rock cylinders pressed down in the uppermost part of surface-based holes, well-compacted moraine and grout.
- *Geosphere.* This system component comprises the rock surrounding the repository and the investigation boreholes. It also includes grout injected into fractures in the rock during construction of the repository to prevent water inflow to tunnels and other repository cavities. In the upward direction, the geosphere is bounded by the biosphere. For boundaries in the other directions, see definitions above regarding the system boundary.
- *Biosphere.* This system component comprises the near-surface properties and processes, both abiotic and biotic as well as humans and human behaviour, see also definitions above regarding system boundaries.

The different system components are also defined by a number of variables and the initial state of these variables and the states during repository evolution. The variables defined for the engineered barrier system components are given in the interim version of the SR-Can Initial state report /SKB, 2004b/. The set of variables defined for each system component is essentially the same as those defined in the SR 97 Process report, except for the buffer component where the update of the process descriptions, see the interim version of the SR-Can Process report /SKB, 2004a/, has resulted in some modifications in the set of variable compared to the SR 97 Process report. It is possible that modifications in the set of variables also for the other system components will be made in conjunction with the update of the process descriptions for these system components Therefore, the variables defined for the interim reporting should be considered as preliminary, except for the buffer system, and they are not further discussed in detail in this report.

2.3 Audit against NEA FEP database

This part of the work started by importing the SR 97 Process report /SKB, 1999b/ into a database. The software selected for the FEP database is FileMaker Pro, Version 5.5. This database programme allows for relational data files, which was utilised in the auditing process. The structure and content of the SR 97 database is described in Section 4.2.

The NEA international FEP database is the outcome of work by the NEA FEP Database Working Group and it consists of two parts; the international FEP List and Project Databases. The audit was carried out using the Project Databases, which is a collection of FEP lists and databases compiled during repository assessment studies in various countries. Version 1.2 of the NEA FEP database includes project-specific records from eight projects. The main features of the repository concept of these projects are given in Table 2-1.

Table 2-1. Projects included in the NEA FEP database version 1.2.

Project	Code	Waste type	Host rock	Engineered barrier system concept
The Joint SKI/SKB Scenario Development Project, 1989	J	Spent PWR/BWR fuel	Crystalline basement	Corrosion resistant copper containers, borehole emplacement with bentonite buffer
NEA Systematic Approaches to Scenario Development, 1992	N	Intermediate and low-level wastes	Hard rock	Steel and concrete packages, emplaced in caverns with cementitious grout and backfill
HMIP Assessment of Nirex Proposals – System Concept Group, 1993	H	Intermediate and low-level wastes	Tuff, Borrowdale Volcanic Group	Steel and concrete packages, emplaced in caverns with cementitious grout and backfill for ILW
AECL Scenario Analysis for EIS of Canadian Disposal Concept, 1994	A	Used CANDU fuel bundles	Plutonic rock of the Canadian Shield	Thin-walled titanium containers, borehole emplacement with bentonite-sand buffer
Nagra Scenario Development for Kristallin, 1994	K	Vitrified waste from reprocessing of spent PWR/BWR fuel	Crystalline basement under sedimentary cover in Northern Switzerland	Thick steel containers, in-tunnel emplacement with bentonite buffer
SKI SITE-94 Deep Repository Performance Assessment Project, 1995	S	Spent PWR/BWR fuel	Crystalline basement (based on geologic data from the Äspö site in south central Sweden)	Fuel, canister, bentonite buffer and tunnel backfill
US DOE Waste Isolation Pilot Plant, CCA, 1996	W	Contact- (CH) and remote handled (RH) Transuranic (TRU) waste	Salt (Salado Formation, New Mexico USA)	Magnesium oxide backfill as chemical conditioner, crushed salt clay, concrete and asphalt seal components
AECL Issues for the 'Intrusion Resistant Underground Structure', 1997	I	Baled and bitumenised LLW from Chalk River Laboratories operations	Large sand ridge	Reinforced concrete vault above the water table

To facilitate the audit against the Project FEPs in the NEA FEP database version 1.2 and documentation of the auditing results a "NEA mapping" file was created. This mapping file links information in the NEA Project data file (PROFEP) with information in the SR-Can database files.

At the start of the audit, the SR-Can files were identical to the corresponding SR 97 files. Because of the separation of the system components buffer and backfill, all but a few processes that belong to the buffer/backfill system in the SR 97 version were duplicated to both the buffer and the backfill system in the SR-Can version. The few exceptions concerned processes that, from the process description, were judged to refer to the buffer system and therefore were copied to the buffer system only.

2.3.1 General auditing procedure and rules

The NEA Project data file (PROFEP) contains 1418 FEPs. In order to make the audit work more efficient, the mapping of the NEA Project FEPs was carried out by a single person (Kristina Skagius), but some general procedures and rules were followed in order to keep expert judgements regarding details in process understanding to a minimum at this stage. These general procedures and rules were defined by the FEP group and were as follows:

- NEA Project FEPs regarded as irrelevant are marked as such and motivated (see 2.3.2 for screening criteria).
- Relevant FEPs occurring outside the system boundary are classified as External factors (see 2.3.3)
- A NEA Project FEP that clearly can be linked to one or several processes, variables or the initial state of one or more variables is linked so.
- Suggestions on modifications of the descriptions of the processes and variables onto which the NEA Project FEPs are mapped are allowed at this stage. These modifications should be documented and all objects for which modifications are suggested should be marked in the database.
- All NEA Project FEPs not readily or fully fitting into one of the above categories are marked as such FEPs for further handling at a later stage.
- The mapping should be based on the FEP description, rather than the FEP name.
- Any associations outside the actual meaning of the FEP that may arise from the FEP description should be documented.

All NEA Project FEPs that could not readily be mapped using the general auditing rules were discussed at regular meetings in the FEP group and decisions were made on the relevance and classification of these FEPs.

2.3.2 Relevance screening

The relevance of each NEA Project FEP for the SKB repository system was judged following relevance criteria defined by the FEP group. The FEP could be screened out if one of the following criteria was fulfilled:

- The FEP is not appropriate for the actual waste, canister design, repository design, geological or geographical setting.

- The FEP is defined by a heading without any description of what is meant by the heading, but from the interpretation of the heading it is judged that the FEP is covered by other NEA Project FEPs.
- The FEP is very general and covered by other more specific NEA Project FEPs.

It should be emphasised that certain aspects given in a FEP description could be relevant for the repository system defined for the SR-Can assessment even if the FEP mainly is related to a system deviating from the SR-Can system. For example, NEA FEPs that are related to concrete barriers in an LLW/ILW repository concept are not necessarily screened out since concrete is part of the SKB repository system and the aspects addressed in the NEA FEP description might therefore be relevant. In these cases, the FEP was judged as relevant and treated further as described in the following sub-sections.

It should also be noted that the general strategy in the screening of FEP relevance has been to judge FEPs as relevant rather than to screen them out at this stage, unless it is clearly obvious that they are irrelevant. By this approach, the decision regarding the FEP relevance and motivations for the decision is left to the different experts that are involved in the further processing of the audit results.

2.3.3 Classification of relevant FEPs

NEA Project FEPs assessed to be relevant for the SKB repository system were classified into one or more of the following categories:

- System process.
- Variable/initial state.
- Biosphere.
- External factor.
- Assessment basis.
- Methodology comment.

System process

This category was used to classify FEPs that were judged to describe a process relevant for one or several of the system components defined for the SR-Can assessment, excluding the biosphere. The biosphere was treated differently because biosphere processes and variables are not included in the previous version of the SKB Process report or FEP analyses related to a KBS-3 repository, see below.

Variable/initial state

This category was used to classify FEPs that were judged to affect a variable defined to describe the state of a system component in the SR-Can assessment, either the initial state of the system component or the state during evolution. In case the FEP is addressing both a process relevant for the evolution of a system component and a variable affected by the process, it is always assigned to the category system process, but not always also to the category variable/initial state. However, all FEPs that were judged to be relevant for the initial state of a system component were assigned to the category variable/initial state.

Biosphere

A separate treatment of biosphere FEPs was necessary because the SR 97 database does not contain any biosphere processes or variables. Therefore, NEA FEPs judged as being relevant for the SR-Can biosphere were classified into a separate category "Biosphere" for later audit or use as input to the selection of processes and variables for the biosphere system component. The biosphere FEPs were also divided into the sub-categories Quaternary deposits, Surface waters, Atmosphere, Biota, Man and Others.

External factor

The category *External factors* was used for NEA FEPs that are acting outside the boundary of the repository system. During the auditing work, a further division was made into the sub-categories "Geological processes and effects", "Climatic processes and effects", "Future human actions" and "Others", i.e. the same classification as is used in the NEA database.

Assessment basis

The category *Assessment basis* was used for FEPs that will not need much further evaluation, but will have to be addressed in the SR-Can safety assessment report where the assessment basis will be defined.

Methodology comment

This category was used for FEPs that describe a general methodology or design issue. These FEPs are not relevant for the evolution of the repository system, but might address issues to be considered when carrying out the safety assessment. Since the distinction between the categories assessment basis and methodology comments is not quite clear, these two categories are grouped together as *Methodology FEPs* in the further processing of the audit results.

2.3.4 Documentation of audit results

The results of the audit were documented in the NEA mapping file in the database. A short description of the type of documentation made is given here. More details and illustrations of the documentation are given in Section 4.3.3

FEP relevance

The relevance of the FEP for the SKB system was documented in the NEA mapping file together with a motivation for the judgement "not relevant", when applicable. Out of the total number of 1418 Project FEPs in the NEA database, 312 FEPs were screened out as being irrelevant for the SR-Can assessment. Examples of screened out FEPs are those related to magmatic activity and volcanism, and FEPs addressing aspects specific for vitrified waste.

Processes and Variables/initial states

All NEA FEPs assigned to the categories "System process" and "Variables/initial states" were marked as such in the mapping file. If the FEP was judged to be covered by a process or variable already included in the SR 97 database, the link to this process was documented in the NEA mapping file in the database. If the FEP could be linked to an SR 97 process, but certain aspects of the NEA FEP was not addressed in the process description, the link to the process was documented in the mapping file together with a marker indicating that modifications of the process description might be needed, and a comment regarding the missing aspect was made. If an NEA FEP was not addressed in the SR 97 database, this was marked and commented on in the mapping file.

The audit results revealed the need of adding a number of processes to the SKB database as well as of highlighting various FEPs of potential relevance for the initial state of the system components. To take care of this, processes were added to the SKB database together with four categories of initial states. These are named "Initial state – General", "Initial state – Mishaps", "Initial state – Design deviations" and "Initial state – Incomplete closure". The earlier mapping of NEA Project FEPs was revisited and updated to match the new list of processes and Initial states.

The number of NEA FEPs assigned to the category "System process" is 520, whereas 160 NEA FEPs were assigned to the category "Variables/initial states".

Biosphere

All NEA project FEPs classified as relevant for the biosphere in the SR-Can assessment were marked as such in the mapping file. Since no biosphere processes are included in the SR 97 Process report, no actual mapping of these FEPs was made. However, based on the structure of the biosphere interaction matrix developed as a part of the most recent safety assessment of the Swedish repository for low and intermediate level waste (SFR), the SAFE project /SKB, 2001/, six biosphere categories were defined. These are: "Quaternary deposits", "Surface waters", "Atmosphere", "Biota", "Man" and "Other". Each NEA Project FEP classified as being relevant for the biosphere was also assigned to one or several of these categories by markers in the NEA mapping file. An attempt was also made to document if the NEA Project FEP matched any of the interactions defined in the SAFE biosphere interaction matrix /SKB, 2001/. This was done in terms of a mapping comment in the NEA mapping file (see also Section 4.3.6). In total, 256 NEA FEPs were assigned to the Biosphere category.

External factors

All NEA project FEPs classified as relevant external factors for the SR-Can repository system were marked as such in the NEA mapping file. In addition, each FEP was marked as belonging to one of the categories "Climatic processes and effects", "Geological processes and effects", "Future human actions" or "Other". Within each of these categories a further sorting of the FEP was made and marked in the NEA mapping file. The sub-categories defined for each of the main categories of external factors are shown in Table 2-2.

The number of NEA FEPs classified as External factors to the SR-Can repository system is 184.

Assessment basis and methodology issues

All FEPs judged to belong to the categories "Assessment basis" or "Methodology issues" were marked as such in the NEA mapping file. The number of NEA FEPs assigned to these categories is 113.

Table 2-2. Heading for different groups within each of the categories of External Factors to which NEA Project FEPs and matrix interactions were sorted during the audit procedure.

Category	Climatic processes and effects	Geological processes and effects	Future human actions	Others
Groups	Climate change – general	Tectonics (uplift, subsidence, plate motions, warping etc)	Repository intrusion	Meteorite impact
	Acid rain and effects	Seismic activity/ earthquakes	Resources – mineral	
	Permafrost and glaciation	Mechanical and hydrological effects	Resources – oil and gas	
	Hydrogeological effects of climate change		Resources – geothermal	
	Climate change – causes		Resources – water	
	Greenhouse gas effects		Storage	
	Mechanical effects of climate change		Surface explosions	
			Underground explosions	
			Administrative (records, markers, planning, control)	
			Earthmoving/ surface disruptions	
			Pollution	
			Urbanisation	
			Archaeological investigations	
			Effects of drilling, mining, explosions	

2.4 Audit against SR 97 interaction matrices

The content of the SKB interaction matrices reported in conjunction with the SR 97 safety assessment was mapped to the content in the SKB FEP database in a similar way as done for the NEA Project FEPs. This mapping is largely similar to the mapping reported in /Pers et al, 1999/ with the exception of a few revisions and the addition of mapping to variables and initial states, which were not done by Pers et al. In addition, matrix interactions related to the biosphere system and considered as external factors to the SR-Can system have not been handled previously.

For carrying out the audit and for documentation of the results, a Matrix mapping file was created. This file comprises a link between a file containing the information regarding all interactions in the SKB Interaction matrices developed for the buffer, the near-field and the far-field /Pers et al, 1999/ and the files in the SKB FEP database. The three Interaction matrices contain in total 646 interactions.

The different categories used for classification of the interactions are the same as those used in the audit against the NEA Project FEPs, namely "System process", "Variable/Initial state", "External factor", "Biosphere", "Assessment basis" and "Methodology comment". For each interaction, this classification is marked in the Matrix mapping file.

Matrix interactions assigned to the categories “System process” and “Variables/initial states” were linked to the appropriate process, variable or initial state record in the SKB database. This link was documented in the Matrix mapping file. If the interaction was not addressed in the SKB FEP database, this was marked and commented on in the Matrix mapping file. Of all interactions defined in the three matrices, 583 were classified as relevant for a system process. The corresponding number of interactions assigned to the category “Variable/initial state” is 60. It should be pointed out that the primary focus of the matrix mapping was to identify the relevant process described in the interaction. Therefore, all variables involved in the interactions are not systematically indicated in the mapping file, unless the interaction clearly is related to the initial state or deviations in initial state of a system component.

Of all interactions in the matrices, only three were classified as belonging to the category “External factors”. These three interactions are related to human intrusion, earthquakes and ice load during glaciation. These three interactions are either already addressed in the process descriptions or covered by NEA Project FEPs. No further treatment of these interactions was therefore made.

Eleven of the interactions were classified as belonging to the category “Biosphere”. Because of this low number, no further division of these interactions into biosphere sub-categories was made at this stage.

35 of the interactions were found to be more of a general methodology or design issue than related to a process, variable or initial state and were therefore assigned to the category “Methodology comment”.

More details and illustrations of the documentation contained in the Matrix mapping file are given in Section 4.3.4.

2.5 Further processing of FEPs lists

The result of the audit against the NEA Project FEPs and the SKB Interaction matrices was used to create check lists for the update of the Process report for the SR-Can assessment and for the preparation of descriptions of the initial states of the repository system components. In addition, FEPs lists from the audit were used as input to the selection of scenarios. The different procedures applied for the post-processing of the audit results are described in this section.

2.5.1 Internal processes

The audit against the NEA Project FEPs and the SKB Interaction matrices, including discussions and decisions made by the FEP group, resulted in a list of proposed internal processes for each system component as well as comments on additions or revisions of the descriptions given in the SR 97 version of the Process report. These lists of internal processes and comments from the audit have been and will be further processed by the experts responsible for preparing the process descriptions in the SR-Can Process report.

At the time of the interim reporting of SR-Can, only the process list for the buffer has been carried through from the audit results to process descriptions for the buffer. These process descriptions are reported in the interim version of the SR-Can Process report /SKB, 2004a/.

So far, all process headings are also included in the SR-Can Process file of the SKB FEP database, but not yet the text describing the processes. For all other system components, the list of processes contained in the database needs to be reviewed and updated by the different experts assigned for the task of updating the SR-Can process descriptions.

The processes contained in the Process file in the SKB FEP database at the time of the interim reporting of SR-Can are listed in Table 1 in Appendix 1 and commented on below.

The list of processes for the system component *Fuel/cavity in canister* is essentially the same as in the SR 97 Process report. Two processes have been added as a consequence of the audit. "Structural evolution" (2.6.X) refers to alteration of the fuel structure due to e.g. radiation damage – alpha recoil and or high temperature. The other process added is "Microbial processes" (2.7.X). This proposed list of processes, the NEA Project FEPs and matrix interactions linked to the processes as well as the comments compiled during the audit needs to be analysed by experts on fuel processes before the final list of processes for the SR-Can Process report is decided.

For the system component *Cast iron insert and copper canister*, no modifications to the SR 97 list of processes have been made, following the audit. However, this list and the information from the audit linked to these processes need further analysis by experts on canister processes for decisions on the final set of canister processes for the SR-Can assessment.

The list of processes for the *Buffer* system shown in Table 1 in Appendix 1 is the result of post-processing of the outcome of the audit by generalists and experts in the field. These persons are Allan Hedin and Patrik Sellin, SKB, and Ola Karnland and Lennart Börgesson, ClayTech. The result of their work is documented in the interim version of the SR-Can Process report /SKB, 2004a/. The main differences compared to the SR 97 list of processes are the addition of a number of new processes and the combination of a number of SR 97 processes. For example, the process "Swelling/Mass redistribution" (4.6.1) includes the SR 97 processes "Swelling", "Mechanical interaction buffer/backfill", "Mechanical interaction buffer/near-field rock" and "Thermal expansion". Transport and retardation processes are modified to describe the behaviour of components in water and gas phase, including radionuclides, while two more general processes are specifically addressing the transport of radionuclides in water and gas phase, respectively.

The system component *Bottom plate in deposition hole* was not considered as a system component of its own in SR 97. The proposed list of processes for this system component should be regarded as very preliminary and needs further processing by experts in order to define the processes to be included in the SR-Can Process report.

The system components *Backfill of deposition tunnels*, *Backfill of other repository cavities*, *Plugs* and *Borehole seals* were not included as separate systems in the SR 97 Process report. The proposed list of processes for the *Backfill of deposition tunnels* contains many buffer/backfill processes from the SR 97 Process report since this set comprised the starting point for the audit. In addition, analogies have been made with the list of SR-Can Buffer processes produced by the experts, but issues still remain concerning some of the processes in the list. Since the design concept for the SR-Can assessment is that the same backfill material as in the deposition tunnels will be used also in other repository cavities, the proposed list of processes for this system component is in essence the same as that for the system component *Backfill of deposition tunnel.* The proposed lists of processes for these two backfill system components as well as the lists proposed for the system components *Plugs* and *Borehole seals* (Table 1 in Appendix 1) are still very premature and need to be further explored by experts assigned for developing the process descriptions.

For the system component *Geosphere*, a number of new processes have been added to the list of SR 97 processes as a result of the audit. Examples are “Earth currents” (10.7.Y) and “Effects on the near-field rock of repository construction and operation” (10.6.Z, 10.7.Z). Further processing of this preliminary process list by geosphere experts will be made as a part of the work with developing process descriptions for the geosphere.

2.5.2 Initial states

All NEA Project FEPs and matrix interactions classified as relevant for the initial state of the different repository components were compiled in lists for further processing, with the purpose of deciding how these FEPs should be handled in the SR-Can assessment. The compilation of FEPs and matrix interactions in these lists were made based on the categories defined for the audit procedure. The processing of these lists was carried out jointly by the following persons: Allan Hedin, SKB, Johan Andersson, JA StreamFlow, Kristina Skagius and Karin Pers, Kemakta.

Initial state FEPs and matrix interactions are related either to expected conditions with variations/tolerances, denoted reference initial state in SR-Can, or to deviations from these expected conditions. The former group of FEPs and matrix interactions should be considered in the description of the initial states of the system components and the latter in the selection and definition of scenarios for the repository evolution. In the FEPs processing, this distinction between FEPs and matrix interactions was made and documented together with additional comments arising during the processing. Thus, the outcome of this FEPs processing is a checklist for the description of reference initial states of the repository system and a checklist for scenario selection. The former list has been used in the preparation of the SR-Can interim version of the Initial state report /SKB, 2004b/ and the latter list of FEPs in the selection of scenarios, which is described in Chapter 8 of the Interim main report /SKB, 2004c/.

A large part of the initial state FEPs simply state that one aspect or the other should be included in the assessment. It was concluded that these FEPs by necessity are part of the description of the reference initial state and were not further discussed. The results of the analysis of the remaining FEPs are summarised in Tables 2 and 3 in Appendix 1, in terms of factors/issues to be considered together with comments on how to handle the issues in SR-Can, and a note on which NEA Project FEPs and Matrix interactions that are the origin of these issues. The content of these tables are briefly commented on below.

Some general issues to consider when defining the initial state of the repository system were identified. These issues are compiled in Table 2 in Appendix 1. Several of the NEA Project FEPs are related to *major mishaps or accidents and sabotage*. It was decided to exclude these types of events from the SR-Can assessment, whereas more “reasonable” mishaps should be included in the main scenario. The reason for excluding severe mishaps from the assessment are; i) the probabilities for such events are low, and ii) if they occur, this will be known prior to repository sealing so that mitigation measures and assessment of possible effects on long-term safety can be based on the specific real event. It was also noted that probabilities for these types of events will depend on technical solutions and handling procedures and therefore will be dependent on the, not yet finalised, selection of these solutions and procedures.

Another group of general issues emanating from the FEPs analysis are related to the *phased operation of the repository*, i.e. effects of actions during repository construction and operation on the geosphere and already completed parts of the repository. This is part of the expected evolution of the repository, but not readily captured in the system of processes that describe the evolution of the system over time. Impacts on the hydrogeology of an open repository will be preliminarily analysed in SR-Can. Other effects will be mentioned in SR-Can, but not analysed.

Effects of unsealed repository or unsealed surface-based investigation boreholes and effects of monitoring are three other groups of factors that should be considered in the scenario selection.

No specific action was decided for a FEP-category related to consequences of model simplifications of repository design other than to keep it in the FEP database for later verification that all safety relevant features have been considered in the derivation of initial state from a given repository design.

Factors/issues related to the different repository system components that, according to the FEP analysis, need to be considered, and the handling of these factors in the SR-Can assessment, are listed in Table 3 in Appendix 1.

Identified issues related to the fuel, such as initial enrichment, burn-up and fuel damage are included in the Initial state report /SKB, 2004b/, as is the inventory of chemically toxic elements. Variability in fuel characteristics between canisters will be addressed in the interim version and fully described in the final version of the SR-Can Initial state report.

The description of the composition of materials in the cast iron insert and copper canister in the interim version of the Initial state report /SKB, 2004b/ includes the inventory of chemically toxic elements. Welding defects are discussed and handled in the interim version of the Data report /SKB, 2004d/, whereas defects due to failure in QA procedures must be further discussed. This is also the case for other potential defects in the copper canister, e.g. material defects, and defects in the cast iron material that affects strength, e.g. graphite structure, slag or cavities. However, normal variations in graphite structure are included in the probabilistic analyses of strength, that are being carried out. Mishandling and breakage of the canister during manufacturing, sealing, transport and deposition should be addressed, based on descriptions of measures to avoid damages and conclusions about likelihoods. This information is expected from the preliminary safety reports for the operation of the encapsulation plant and the deep repository. Other types of mishaps, e.g. tools and other materials accidentally lost in the void between canister and buffer, will be further elaborated.

The description of the composition of materials in the buffer and the bottom plate of the deposition hole in the interim version of the Initial state report /SKB, 2004b/ includes the inventory of chemically toxic elements. The Initial state report also includes a specification of impurities and stray materials that considers effects of spillage of oil, hydraulic fluids, organic solvents, nitrous compounds, common corrosive chemicals etc. Factors that should be considered in the selection of scenarios for SR-Can are related to mishaps/problems during emplacement and deviations in material compositions, despite quality control. Faulty or deviating emplacement of the buffer might be caused by, e.g. difficulties due to inflow of water or problems with remote control handling, and may lead to an inhomogeneous buffer and/or reduced density of the buffer.

The results of processing FEPs related to the backfill of tunnels and plugs are similar to the results for the buffer and bottom plate of deposition holes. The inventory of chemically toxic elements is given in the Initial state report /SKB, 2004b/ as well as a specification of impurities and stray materials that considers effects of various spills during construction and operation. Similarly, factors related to mishaps/problems during emplacement and deviations in material composition despite quality control are considered in the scenario selection. Some additional features identified concern the possibility of fracturing of the plugs in deposition tunnels during maturing and degradation /corrosion of reinforcements during operation. These should be considered when specifying the initial state. The latter issue is addressed in the Initial state report /SKB, 2004b/, but no detailed analyses will be carried out in SR-Can. Fracturing of plugs is an issue that has to be addressed in the main scenario.

Some factors identified were related to various types of boreholes. Injection boreholes and grouting practices in tunnels and other repository cavities as well as grout composition are described in the Initial state report /SKB, 2004b/. The location and geometry of investigation boreholes are part of the description of the initial state of the geosphere, which is provided by the Site descriptive model /SKB, 2004e/, whereas poorly sealed boreholes will be considered in the selection of scenarios.

Factors related to the geosphere concerned changes in repository geometry due to rock fallout during construction and operation and effects of saline water intrusion during operation. Description of the repository geometry is part of the reference initial state of the system and included in the Initial state report /SKB, 2004b/. Potential rock fallout and impacts on the buffer in deposition holes or on backfill in tunnels are further evaluated in the selection of scenarios. Intrusion of saline water during construction and operation is part of the main scenario in SR-Can.

2.5.3 External factors

As already described in Section 2.3.4, NEA Project FEPs and Matrix interactions defined as External factors to the repository system were classified into the following four categories: "Climate processes and effects", "Geological processes and effects", "Future Human Actions", and "Others". Within each category, the FEPs were further divided into groups depending on the content of the FEP (see Table 2-2).

In the processing of the list of FEPs in the different categories of External FEPs, climate and large-scale geological FEPs were compared against the plans for modelling these phenomena, and FEPs related to future human actions were compared to the handling in SR 97, which forms the basis for the handling in SR-Can. This audit was carried out by Allan Hedin and Lena Morén, SKB, Johan Andersson, JA Streamflow, and Karin Pers, Kemakta. A general conclusion from the audit was that most of these FEPs were handled in SKBs latest safety assessment SR 97 /SKB 1999a/. The results for the different group of FEPs are briefly commented on below.

Climatic processes and effects

FEPs in this category were, during the audit, sorted into different groups based on the FEP description (see Table 2-2). *Climate change – general* contains FEPs that generally state that future climate change may affect the performance of the repository. The heading *Permafrost and glaciation* was used for FEPs related to the establishment of future glaciation and permafrost conditions. *Hydrogeological effects of climate change* contains FEPs related to all possible hydrogeological effects of future climate change such as changes in sea level, flood, drought and ice sheet effects. *Mechanical effects of climate change* contains FEPs related to, e.g. loading effects of an ice sheet. *Climate change – causes* contains FEPs that address possible causes for a change of the expected future change towards a colder climate such as reversal of the earths magnetic poles and destruction or damage to the ozone layer. *Greenhouse gas effects* was used as heading for a group of FEPs related to the potential effects on climate of greenhouse gases. *Acid rain and effects* contains FEPs that addresses acid rain and the potential environmental impact of acid rain.

The processing of FEPs related to climatic processes and effects revealed that the FEPs sorted to the different groups were already included in the plans for the main scenario defined for SR-Can. Concerning the group *Acid rain and effects* it was specifically noted that acidification is handled in studies of the biosphere and that the impact of acidification on the geosphere should be addressed in the appropriate process description. Furthermore, FEPs related to human induced acid rain are in the assessment handled as FEPs in the category Future Human Actions, sub-group "Pollution". The documentation from the processing of this category of External Factors is given in Table 4 in Appendix 1 together with the NEA Project FEPs sorted to the various groups.

Geological processes and effects

FEPs in this category are related to natural tectonic movements like land uplift, subsidence and warping, to earthquakes and seismic activity, and to mechanical and hydrogeological effects of these types of events (see Table 2-2). In addition, FEPs related to the intrusion of natural gas was compiled in this category.

FEPs sorted to the different groups in this category was reviewed and it was concluded that these groups are to be considered in the main scenario defined for the SR-Can assessment (see also Table 5 in Appendix 1).

Future Human Actions

The NEA Project FEPs sorted to the category FHA were divided into a number of groups based on the content of the FEP description (see Table 2-2). The groups related to repository intrusion, future exploitation/exploration of resources like minerals, water and geothermal energy and archaeological investigations are considered in the selection of scenarios, whereas resources like oil and gas are assessed as not relevant for the repository site conditions. Potential storages of other wastes in the vicinity of the repository is another group of FEPs that are considered in the selection of scenarios for the SR-can assessment as are FEPs related to surface explosions, e.g. bomb blasts at the surface, and human actions resulting in pollution of the surface and groundwater. Underground explosions related to construction works are also included in the scenario selection, whereas underground nuclear tests were judged as unlikely. Administrative FEPs, like loss of records or markers or institutional control, are included in the selection of scenarios as are FEPs related to underground excavations caused by urbanisation and effects of drilling, mining and explosions in the vicinity of the repository. However, the group of FEPs related to earthmoving and surface disruptions was assessed as being of no relevance for a deep repository (see Table 6 in Appendix 1).

Others

All FEPs sorted to this group were related to meteorites and the impacts on repository performance. Since it was assessed that the effects of meteorite impact is more severe than damage to the repository, this group of FEPs are not considered in the assessment (see Table 7 in Appendix 1).

2.5.4 Biosphere FEPs

No further processing of the NEA FEPs and Matrix Interactions classified as relevant for the biosphere has been carried out within the framework of the interim reporting of SR-Can. However, these FEPs and Interactions are compiled in a separate file in the SKB FEP database and are thus readily accessible for further processing in connection with the development of process descriptions for the biosphere system.

3 Summary and status of FEP analysis at time of interim reporting

Figure 3-1 shows a flow chart of the FEPs processing carried out for SR-Can. The starting points for the SR-Can FEP handling are FEPs in *i*) the SKB interaction matrices, *ii*) the SR 97 processes as documented in the SR 97 Process report and *iii*) the NEA international FEP database with a number of national databases linked to it (a in Figure 3-1). These FEPs were sorted into three main categories (b in Figure 3-1): *i*) initial state, *ii*) process and *iii*) external FEPs. Biosphere FEPs were compiled and documented in the database (see Section 4.3.6), but remain to be further handled. FEPs were also categorised as irrelevant or as being related to methodology on a general level. This latter group of FEPs are also documented in the FEP database (see Section 4.3.8).

Initial state FEPs were either *i*) included in the initial state description in SR-Can /SKB, 2004b/, i.e. the reference description of the KBS-3 repository, the site description or the site specific layout of the repository or *ii*) propagated to the scenario selection in case they describe circumstances outside the reference conditions (see Section 2.5.2). The result of this processing of FEPs is not included in the SR-Can interim version of the FEP database, but will be documented in its final version.

Process FEPs were used to update the SR 97 set of internal processes for the engineered barrier system and the geosphere (d in the figure). The resulting SR-Can set of processes for the buffer are documented in the interim version of the SR-Can Process report /SKB, 2004a/ and as process headings in the SR-Can interim version of the database. Preliminary lists with SR-Can processes for the remaining system components are presently available in the interim version of the database, but these lists will be further processed and documented in the final version of the SR-Can Process report (see Section 2.5.1).

External FEPs related to climate and large-scale geosphere processes were audited against the plans for handling these phenomena in SR-Can, which build on the treatment in SR 97 (e in Figure 3-1 and Section 2.5.3). The only “other” external FEP, meteorite impact, was dismissed as having extreme direct consequences. The results of processing of these groups of External FEPs are not documented in the interim version of the SR-Can database, but will be so in its final version.

External FEPs related to future human actions (FHA) were audited against the FHA FEP treatment in SR 97. The coverage was found satisfactory (see Section 2.5.3). The results are not documented in the interim version of the SR-Can database, but will be so in its final version.

Following scenario selection and modelling, an evaluation of the comprehensiveness of the selected scenarios and of the FEP handling will be carried out (g in Figure 3-1). According to present plans, the result of this formal verification of handling of FEPs in SR-Can will be documented in the database, and plans for handling issues emerging from this activity will be developed.

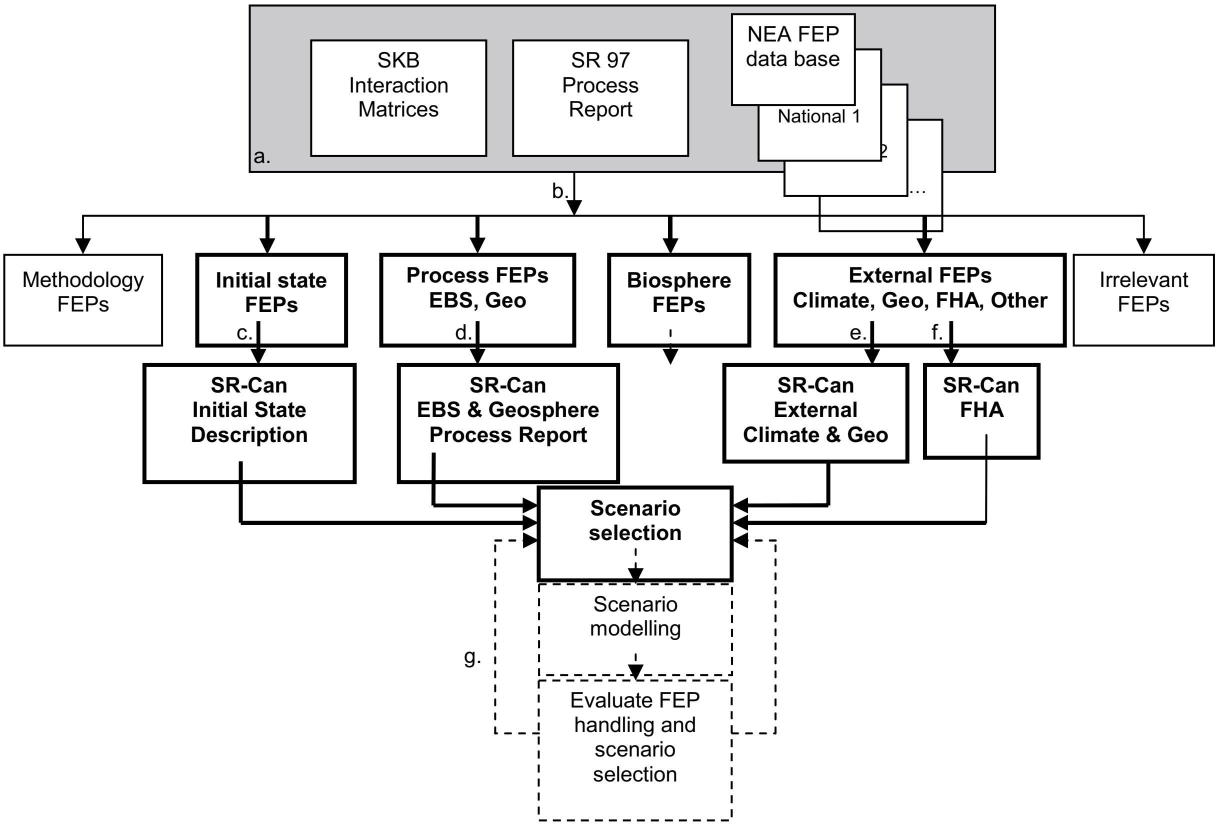

Figure 3-1. *Flow chart of the FEPs processing carried out for SR-Can.*

4 Structure and content of the SKB FEP database

This chapter contains a description of the structure of the FEP database developed for documentation of the processing of FEPs and the results in terms of internal processes, initial states and external factors. As indicated in the previous chapters, this interim version is not totally in phase with the work that has been carried out up to the time of the interim reporting of the SR-Can assessment. More development is needed for taking care of the results of the audits of Initial State FEPs and FEPs related to External Factors against the plans for the SR-Can assessment as well as for the planned documentation of a formal verification of the handling of FEPs in SR-Can.

4.1 Main structure and content

The database is created with the database programme FileMaker Pro, Version 5.5. This programme allows for relational data files, which is utilised in the SKB FEP database. The present version of the database is delivered as a runtime version, which means that the database can be used without having access to the programme Filemaker Pro, Version 5.5.

The database contains files with all the source information used in the FEP analysis and development of the SR-Can database as well as files displaying the results of the audit against the NEA FEP database and the contents of the SKB Interaction matrices and further processing of the audit results. The files with the information contained in the SR 97 Process report /SKB, 1999b/, in terms of descriptions of the different system components, process descriptions, variable definitions and literature references, are defined as the SR 97 version of the FEP database. The remaining files are defined as belonging to the SR-Can version of the database. In the future, when the FEP database once more will be updated in connection with a safety assessment, e.g. SR SITE, a new block of files similar to the SR-Can block of files will be added to the database. In this way the history of the development of the database will be kept.

The SR 97 version or the SR-Can version of the database is accessed by clicking the appropriate button in the start menu that is displayed on the screen when the database is opened (Figure 4-1). The content and structure of the SR 97 version and the SR-Can version of the database is described in more detail in the following sections.

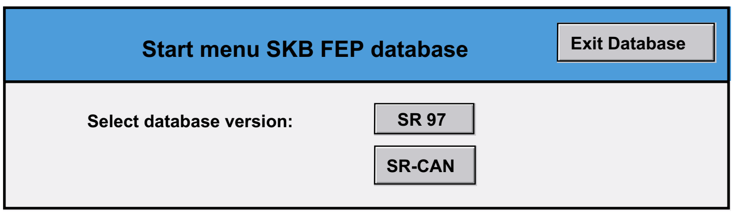

Figure 4-1. *Start menu in the SKB FEP database.*

4.2 SR 97 version

4.2.1 Content and structure

The SR 97 version of the database contains four files with information from the SR 97 Process report /SKB 1999b/. These files are structured in the following way:

- One file contains records with descriptions of each system component, i.e. fuel/cavity in canister, cast iron insert and copper canister, buffer/backfill and geosphere. The descriptions correspond to Sections X.1 and X.2 (X = 2 to 5) in the "Process report". This file also contains a record for the "Surroundings", which is needed for the automatic generation of process diagrams (see Section 4.2.3). This record is empty since the system outside the disposal system was not described in the SR 97 Process report.
- One file contains all Process descriptions from the Process report, one record for each process in each system component. In addition, protocols for the expert judgement of the importance of interactions between each process and each variable in each system component are included here as well as automatically generated process diagrams.
- One file contains the definitions of all system variables, one record for each variable in each system component. The definitions are those given in Tables in the Process report and selected parts of the descriptions in Section X.1 (X = 2 to 5) in the "Process report".
- One file contains all literature references in the "Process report".

When the SR 97 version is selected in the database start menu (Figure 4-1) a start menu for the SR 97 version is displayed on the screen (see Figure 4-2). Return to the database start menu is via the button "Select version". Clicking on the square named System components opens the data file with descriptions of system components. Clicking on the square EBS and Geosphere Processes and Variables gives entrance to the data files with process descriptions and with descriptions of variables. The square "References" gives entrance to the data file with literature references. A more detailed description of each data file is given in the following sub-sections.

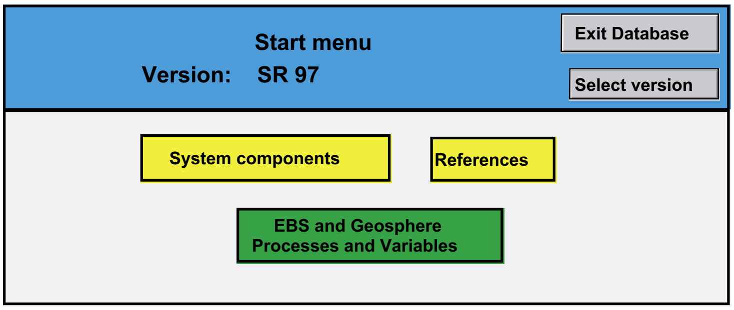

Figure 4-2. *Start menu in the SR 97 version of the database.*

4.2.2 System components

When the square "System components" in the start menu is clicked, a list with the names of the system components is displayed. By clicking the button "Description" a system component is selected and the headings for the description of the system component are shown (see Figure 4-3). The description under a heading is displayed when clicking the button Enter/show. There are also buttons for returning to the list with system components (List system components) and for going to the start menu for the SR 97 version or the SR-Can version.

Figure 4-4 shows the layout for a description under the heading General. The layout for the other headings is the same. The buttons to the right give access to the descriptions under the other headings and to references and figures that are referred to in the text.

References are listed in the same way as in the text, i.e. a short version. The full reference is shown by clicking the button "Show" under "Full reference" in the layout accessed when clicking the button References. The full reference is displayed in blue print (see Figure 4-5), which means that this field belongs to another data file. In this case it belongs to the data file with references and the relational key between the two data files is the short reference. It is possible to move to the data file References to see the whole reference record by clicking the button "Select this reference" (see Figure 4-5) and to return from the reference record to the system description record by pressing the button "Return to component description" in the reference data file (see Figure 4-13).

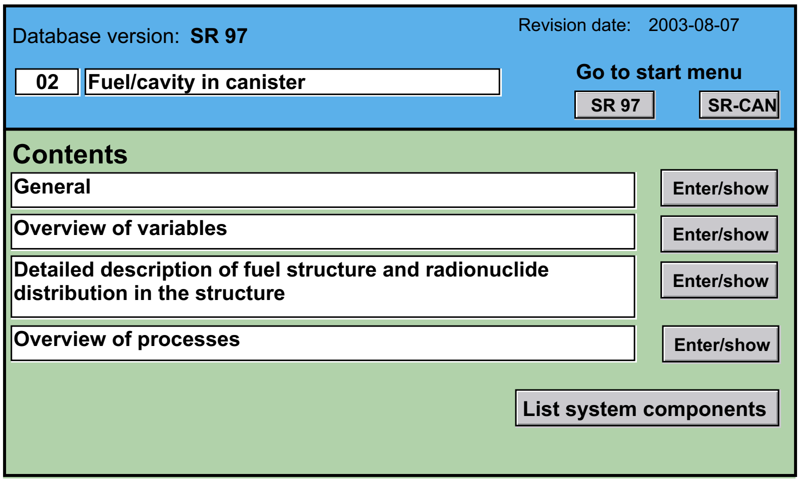

Figure 4-3. *Layout with headings for description of a system component.*

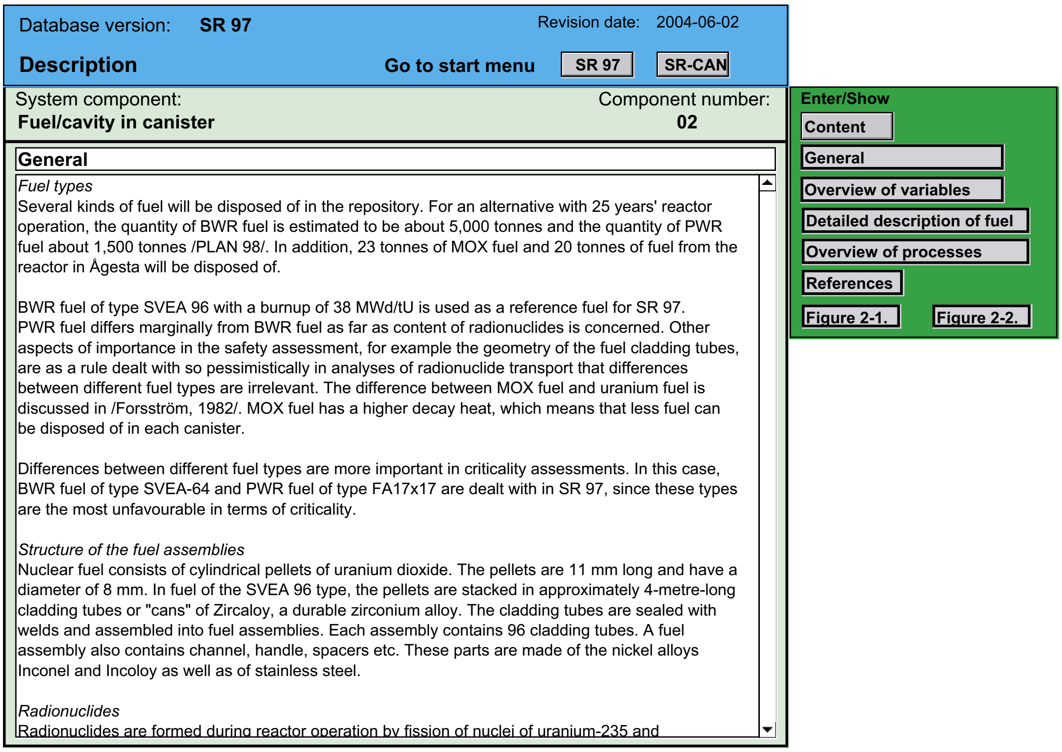

Figure 4-4. *Layout for a description under the heading "General".*

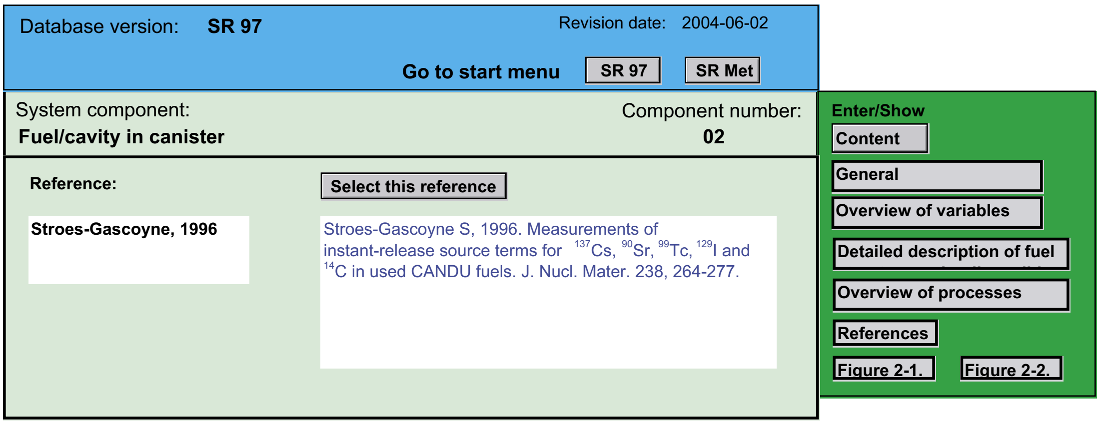

Figure 4-5. *Layout in the system component file that shows the full reference field in the reference file.*

4.2.3 EBS and geosphere processes and variables

The data files with descriptions of Processes and Variables are entered by clicking the square EBS and Geosphere Processes and Variables in the Start menu (see Figure 4-2). In this way the Main menu for Processes and Variables is displayed on the screen (see Figure 4-6).

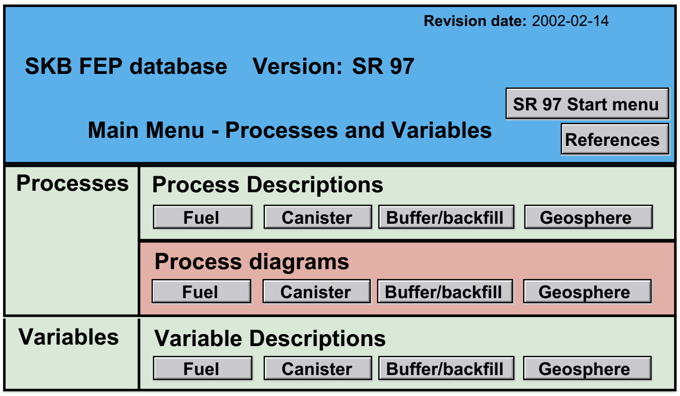

Figure 4-6. *Main menu for the data files with Process and Variable descriptions in the SR 97 version of the database.*

Process descriptions

The buttons under the heading Process Descriptions will display a list of processes for the selected system component and the buttons under the heading Process diagrams will show the SR 97 Process diagram for the selected system component. This diagram is automatically generated from protocols in the Process data file. This is further described below. A copy of the figures of the Process diagrams in the Process report is included in the data file with System component descriptions and these figures are displayed via the appropriate Figure button in the data file with system components, described in the previous section.

From the list of Processes entered via the buttons under Process descriptions, the description of a process is displayed via the button "Description". It is also possible to display a list of processes for the other system components or to return to the SR 97 Main menu via the other buttons in the layout.

Clicking the button "Description" for a process will display a layout with the Process name, the system component it belongs to, adjacent system components, type of process (Radiation-related, Thermal, Hydrological, Mechanical, Chemical or Radionuclide transport), a process number, the source of information, and the content of the description in terms of headings and a few words of the description under each heading (see Figure 4-7). The source of the process descriptions is the SR 97 Process report and the process number is the section number in the Process report.

Via the buttons under Enter/Show in the layout displaying the contents of a process description (Figure 4-7) the whole description under the selected heading is shown. It is also possible to return to the SR 97 Main menu (Figure 4-6) or to display the list of processes for the different system components (buttons in the green field to the right in Figure 4-7). The button "System variables and process diagrams" will display a layout with all variables defined for the actual system component. This is described further below.

The layout showing the text under each heading (see Figure 4-8) is similar to the layout for the description of system components. The buttons in the green field to the right display the text under the other headings or show the Figures belonging to the process description. The button "References" will display a list with all references in the text for the actual process. Clicking the button Show full reference in the reference list will display the full reference from the reference data file, in the same way as is done in the System component data file (see Figure 4-5).

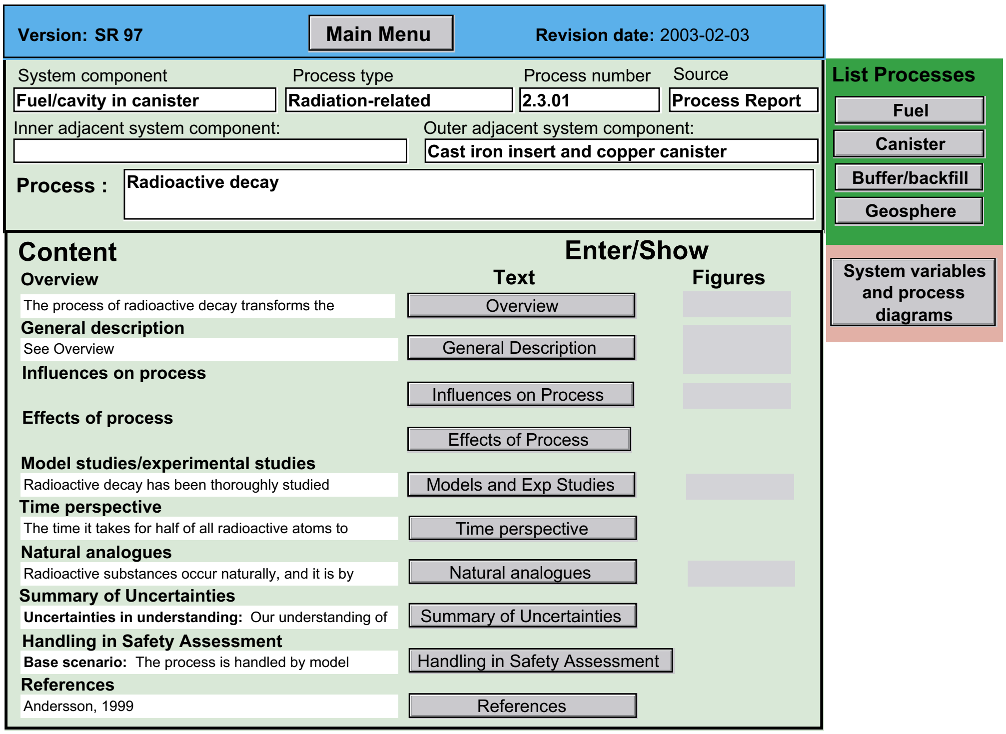

***Figure 4-7.** Layout displaying the contents of a process description.*

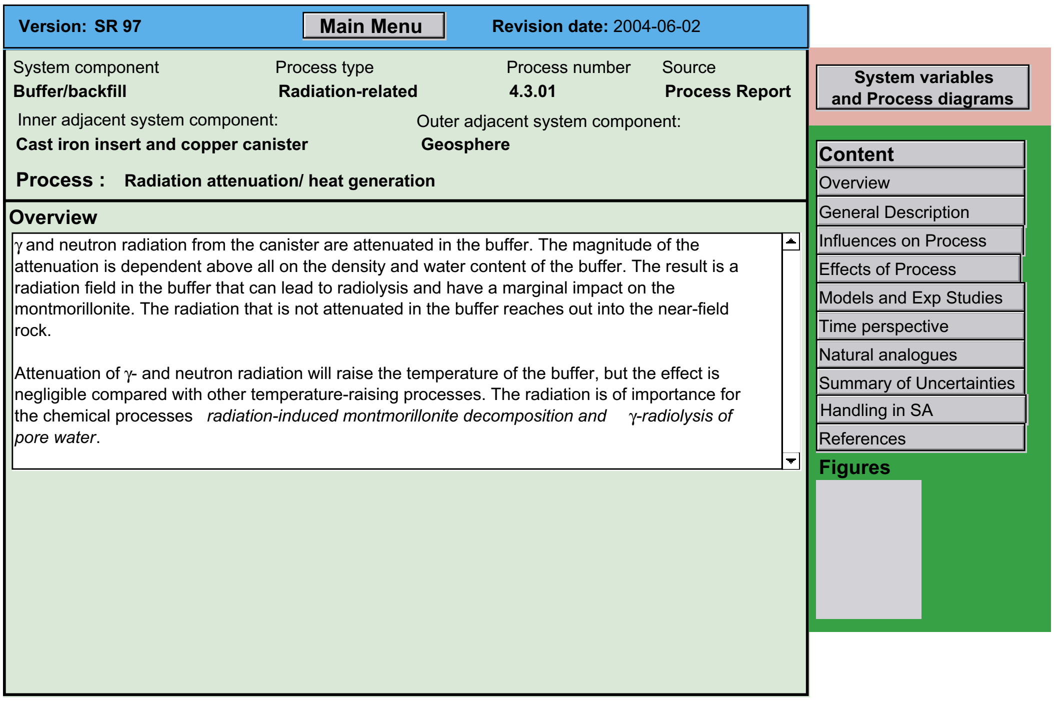

***Figure 4-8.** Layout for the description under heading "Overview".*

Process diagrams

Clicking the button “System variables and process diagrams” will display a list of all variables defined for the actual system component (see Figure 4-9). These variables are fetched from the Variable data file and are shown in blue print. Any modifications in variable names or new variables added to the Variable data file will automatically appear in the variable list in the Process data file. The information shown in this layout together with the information in the judgement protocols entered via the button “Judgement show” is the basis for the automatic generation of process diagrams. The information under the heading Classification of Process in the layout shown in Figure 4-9 defines whether it should be any interaction arrows over the system boundaries or not. If the process interacts over the system boundary the direction has to be defined and a specification of the interaction given in the appropriate fields to the left in the layout.

The protocols entered via the button “Judgement show” define the location and direction of the arrows for the internal interactions between the process and the variables defined for the system component. The protocol for judgement of interactions between the variable Temperature in the system component buffer/backfill and the process “Montmorillonite transformation” is shown in Figure 4-10. The button “Show definition”, displays the definition of the variable as given in the Variable data file. By marking Yes or No in the fields “Influence on process” and “Affected by process” the presence of an interaction between the actual variable and the process is judged. If no judgement is made here and none of the alternatives are marked, a question mark will appear in the automatically generated process diagram. In the SR 97 version of the database, these fields are marked in accordance with the information in the process diagrams in the Process report.

No strict judgement of the importance of the interactions is given in the SR 97 Process report. However, in order to prepare for this option in forthcoming updates of the database, fields for assessing the importance of the interactions and for giving a motivation to the assessment are included.

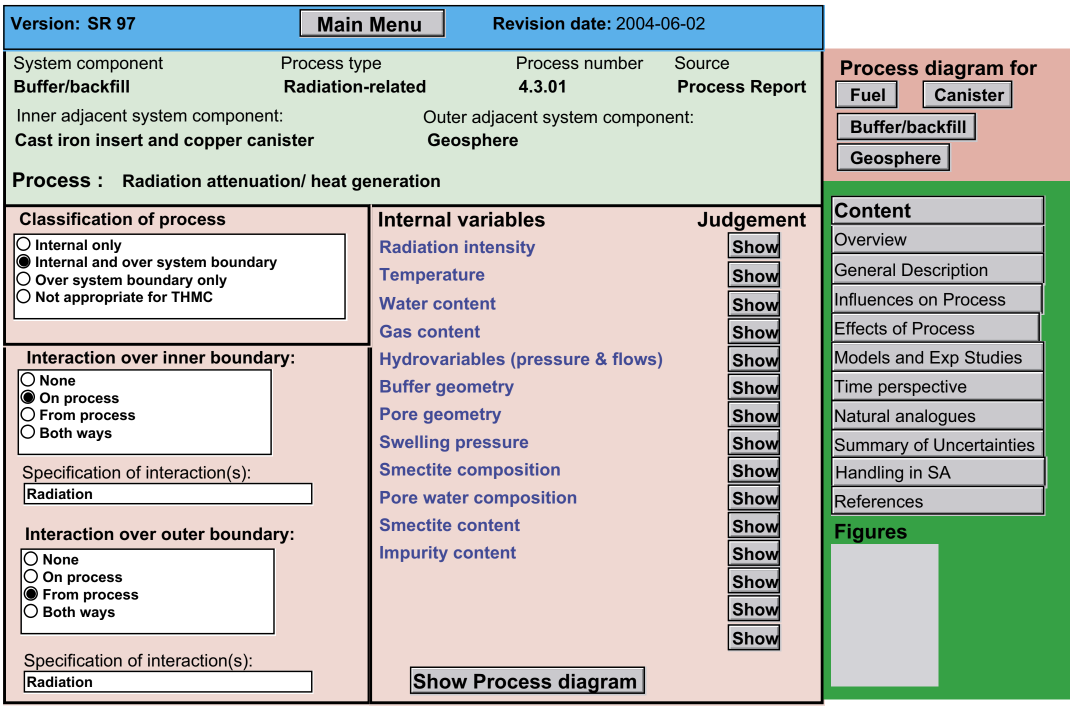

Figure 4-9. Layout showing the variables defined for the actual system component.

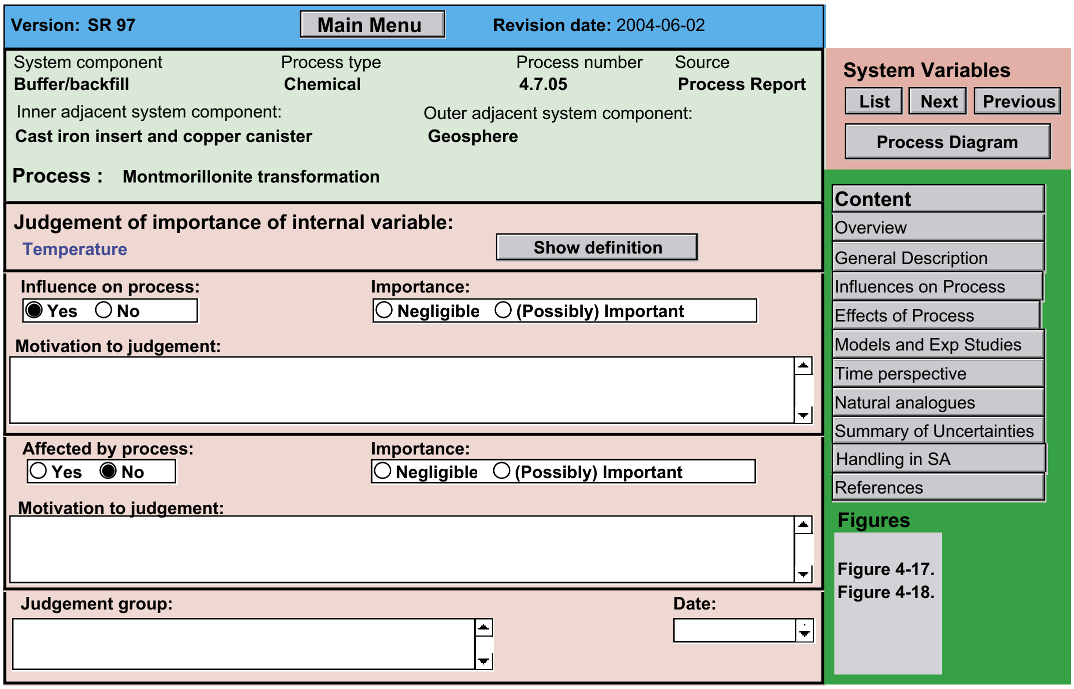

Figure 4-10. *Example of a judgement protocol for automatic generation of process diagrams.*

The button "Process Diagram" displays a diagram for the actual process based on the information in the judgement protocols (see Figure 4-11). From this layout it is possible to return to a judgement protocol or to the layout listing all system variables or to display the process diagram for the entire system component. The process diagram for a system component is also reached directly from the SR 97 Main menu (see Figure 4-6).

Variables

The Variable data file is entered from the SR 97 Main menu via the buttons under the heading "Variable description" (see Figure 4-6). A list of the variables defined for the selected system component will appear on the screen and the definition and a description of the selected variable is shown via the button "Description" (see Figure 4-12). The definition is as given in Tables X.1 (X = 2 to 5) in the SR 97 Process report /SKB, 1999b/. This is also the field that is displayed via the button "Show definition" in the Judgement protocol in the Process data file (see Figure 4-10). The description/initial state field contains text from Sections X.1 (X = 2 to 5) in the SR 97 Process report that is associated with the variable in question. A list of references is displayed via the button "References" and buttons with a Figure label display Figures from the SR 97 Process report associated with the variables.

4.2.4 References

All literature references in the SR 97 Process report are compiled in the Reference data file. This file can be accessed from the SR 97 Database start menu by clicking the square "References" (see Figure 4-2) and also from the System component, Process and Variable data files via the layouts showing the list of references and the full reference.

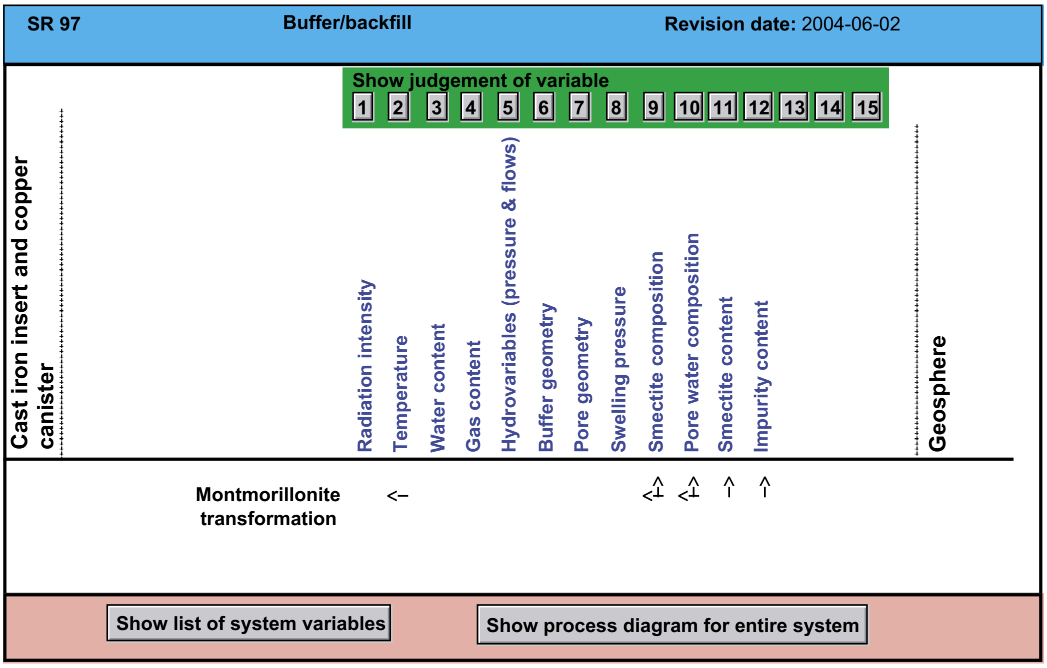

Figure 4-11. Layout showing the process diagram for the process Montmorillonite transformation.

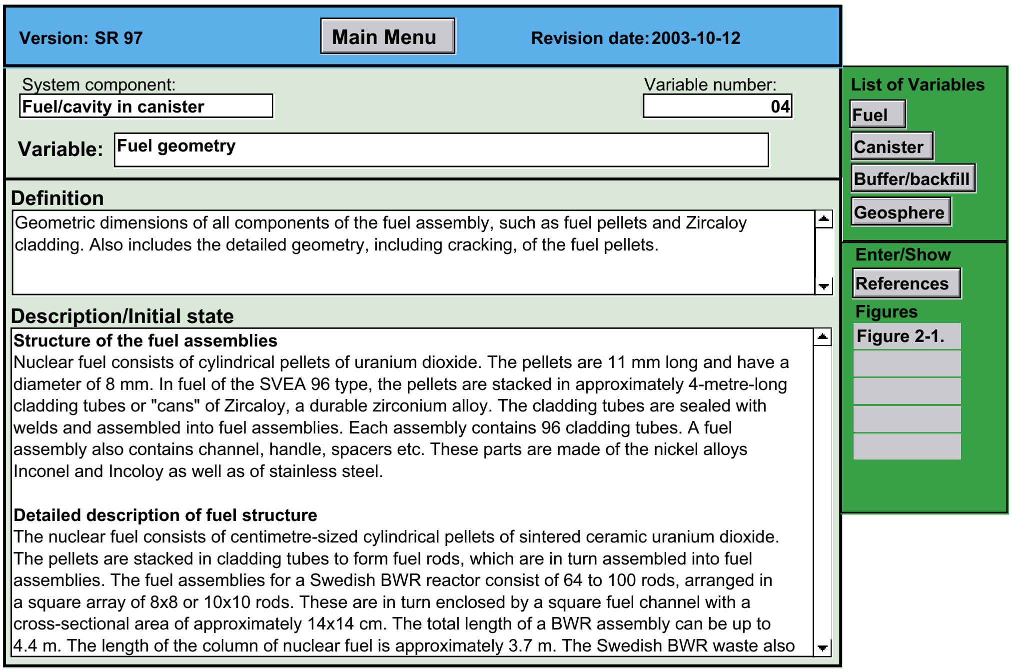

Figure 4-12. Layout for showing variable definitions.

The layout accessed when entering via the button “Select reference” in the System component, Process or Variable data files is shown in Figure 4-13. To return to the original record in one of these files the button Return to “Process description” or “Variable description” or Component description” is used. It is foreseen that the Reference data file will be further developed in conjunction with the update of the descriptions of processes, variables etc for SR-Can, e.g. to simplify the addition of new references to the reference data file and to descriptions of System components, Processes and Variables.

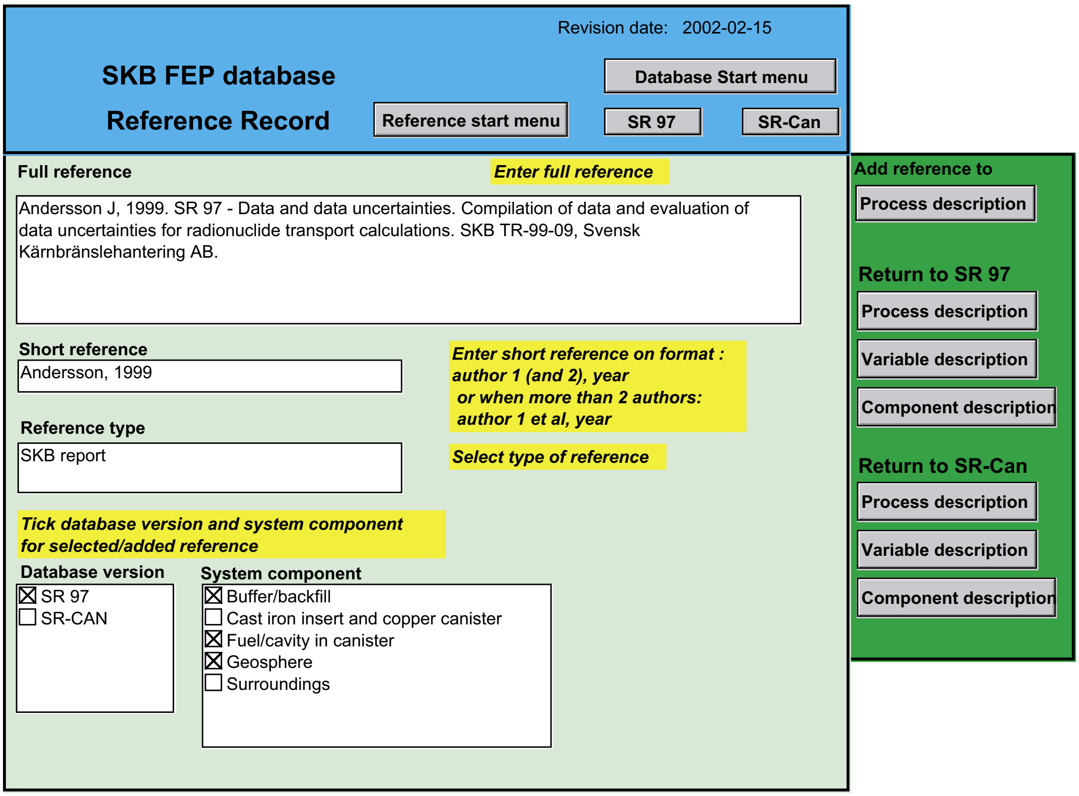

Figure 4-13. *Layout showing a reference record in the reference data file.*

4.3 Interim version of SR-Can

The following sections describe the structure and content of the SR-Can database at the time of the interim reporting.

4.3.1 Content and structure

The structure of the SR-Can database builds on the structure of the SR 97 version. Likewise to the SR 97 version, records for description of the system components are included in a system component file and records for descriptions of processes and variables/initial states are compiled in separate files. The reference file with records of all literature references is the same as the file used for reference records in the SR 97 version. These files are entered by clicking the appropriate buttons in the SR-Can start menu (see Figure 4-14). The SR-Can start menu is accessed from the start menu of the SKB FEP database (Figure 4-1) and also from several other layouts via a button marked SR-Can.

The SR-Can version of the database also contains a number of files for documentation and displaying the results of the FEP analyses carried out. The NEA and Matrix mapping files contains records for all NEA Project FEPs and all matrix interactions with documentation of how each of these has been classified and sorted in the audit of the SR 97 Process report against these sources. In addition, the database contains files for displaying the results of the audit in terms of FEPs and matrix interactions categorised as Methodology issues, External factors and Biosphere FEPs, respectively, as well as for displaying all FEPs assessed as irrelevant for the SR-Can assessment. These different files of the SR-Can database are further described in the following sections.

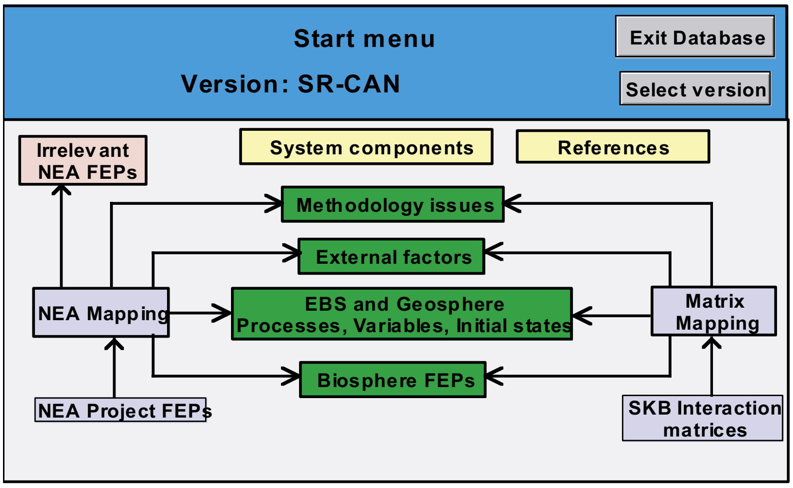

Figure 4-14. Start menu in the SR-Can version of the database.

4.3.2 System components

The same data file is used for documentation of the system components in the SR-Can version as in the SR 97 version of the database. The difference is that SR-Can contains more records because of more system components. Increasing the number of system components means that the numbering of the components is modified compared to the SR 97 version. The numbering of the system components in the SR-Can version is evident from Figure 4-15, which shows the layout listing the system components included in the SR-Can version. This layout is accessed when clicking the square named "System components" in the SR-Can start menu (see Figure 4-14).

In the interim version of the SR-Can database, the records for description of the different system components are empty. However, the layouts showing the different text fields of the records are the same as in the SR 97 version and the different layouts are accessed in the same way as in the SR 97 version (see Section 4.2.2)

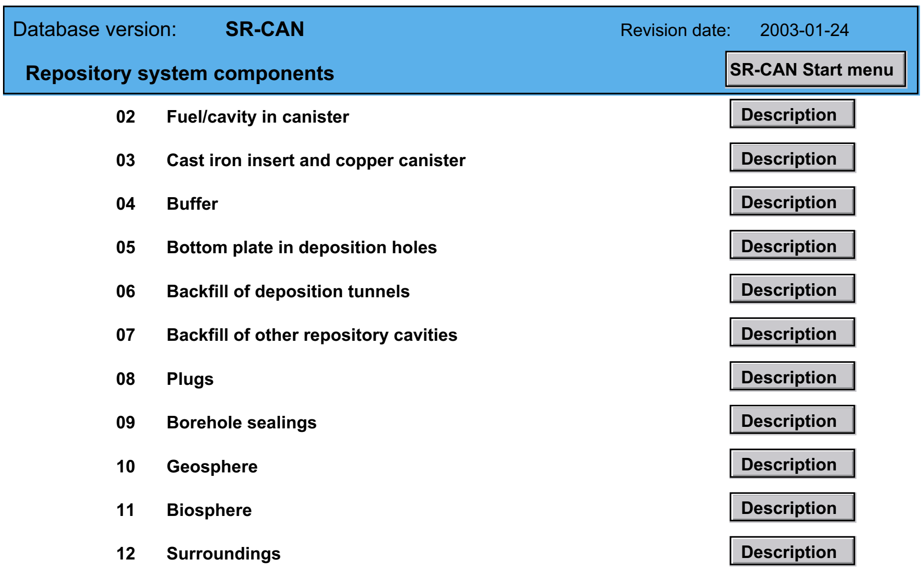

Figure 4-15. Layout showing list of system components included in the SR-Can version.

4.3.3 NEA mapping file

The judgement of each NEA project FEP in the audit is documented in a separate file in the SR-Can version of the database. This file/register links information in the file with project FEPs in the NEA FEP database with the SR-Can file. The NEA mapping file is accessed by clicking the square "NEA mapping" in the SR-Can start menu (see Figure 4-14). The layout entered in this mapping register is shown in Figure 4-16. In this layout the judged relevance of the NEA FEP and part of the mapping results are compiled.

In the heading of this layout there are two buttons, one for returning to the SR-Can start menu and one for entering the first of a number of layouts that were used as tools in the actual mapping procedure. These tool layouts are not further described here, but they are accessed via light grey buttons. In some of these layouts, comments and decisions made during the mapping procedure are documented, i.e. they show to some extent the history of the mapping. All layouts that are showing the final results of the mapping are accessed via dark grey buttons.

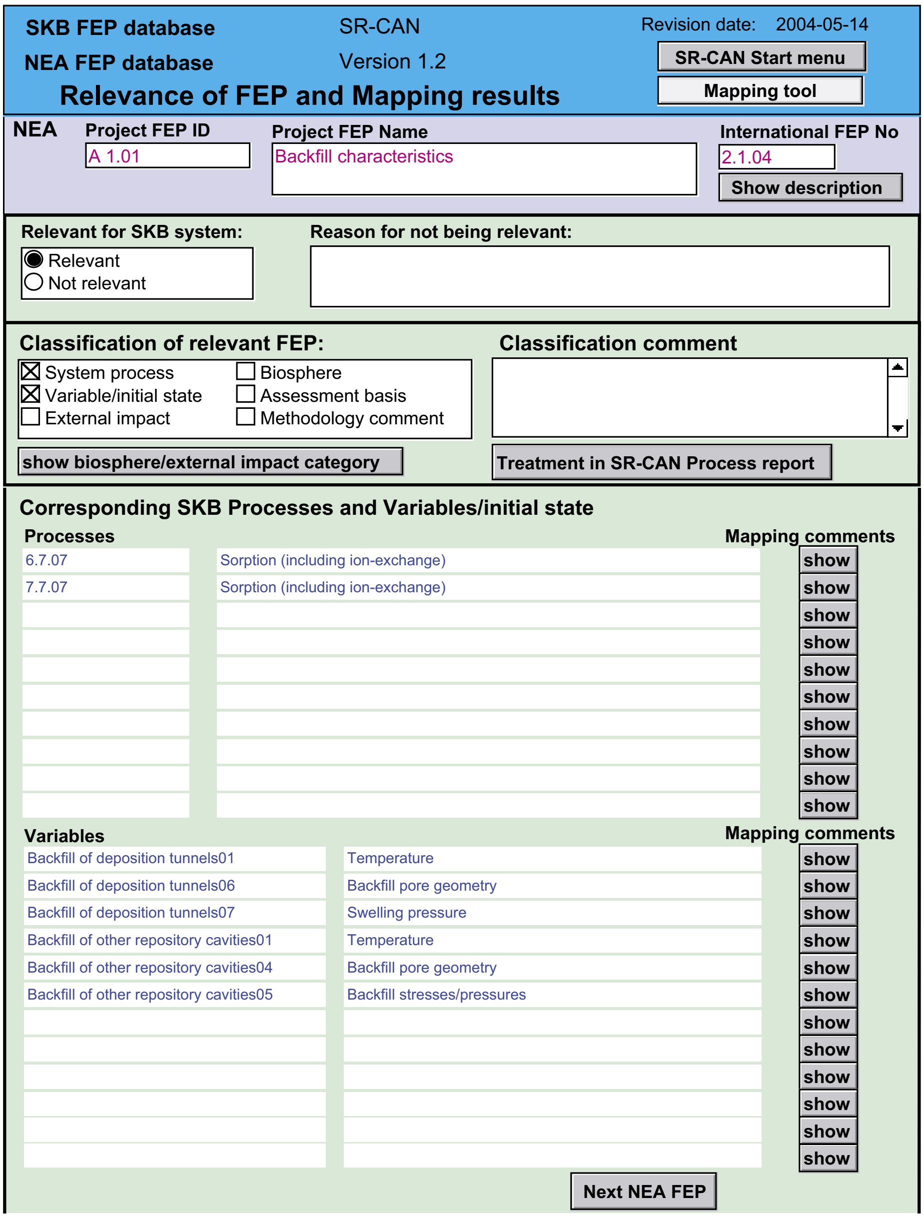

Figure 4-16. *Layout in the mapping register showing the judged relevance of the NEA project FEP and other mapping results.*

In the upper part of the layout, fields from the NEA Project data file (PROFEP) are displayed in red print. The information displayed is the Project FEP identity number in the NEA database, the Project FEP name and the NEA International FEP No to which the Project FEP is mapped in the NEA database. Via the button "Show description" the field with the Project FEP description in the NEA Project data file is displayed (see Figure 4-17). To get back to the Relevance and mapping results layout the button "mapping results" in the lower left corner of the layout is clicked.

In the upper green square of the layout "Relevance of FEP and mapping results" (Figure 4-16), the judged relevance of the NEA Project FEP for the SKB system is marked. For NEA project FEPs assessed to be not relevant, the reason for the judgement is given in the field to the right. This layout also shows the classification of relevant NEA project FEPs into the categories system process, variable/initial state, external impact, biosphere, assessment basis or methodology comment. Depending on the NEA project FEP descriptions one or several of these categories were judged to be relevant.

For FEPs assessed to belong to the group Biosphere and External impact (factors) a further sorting into categories were made. This is shown in a layout entered via the button "show biosphere/external impact category" in the layout Relevance of FEP and Mapping results (Figure 4-16). An example of this sorting into categories is shown in Figure 4-18. These different categories of Biosphere and External impact FEPs are further described in sections 4.3.6 and 4.3.7. Return to the layout "Relevance and mapping results" is via the button "Mapping results" in the layout Biosphere/External impact category (Figure 4-18).

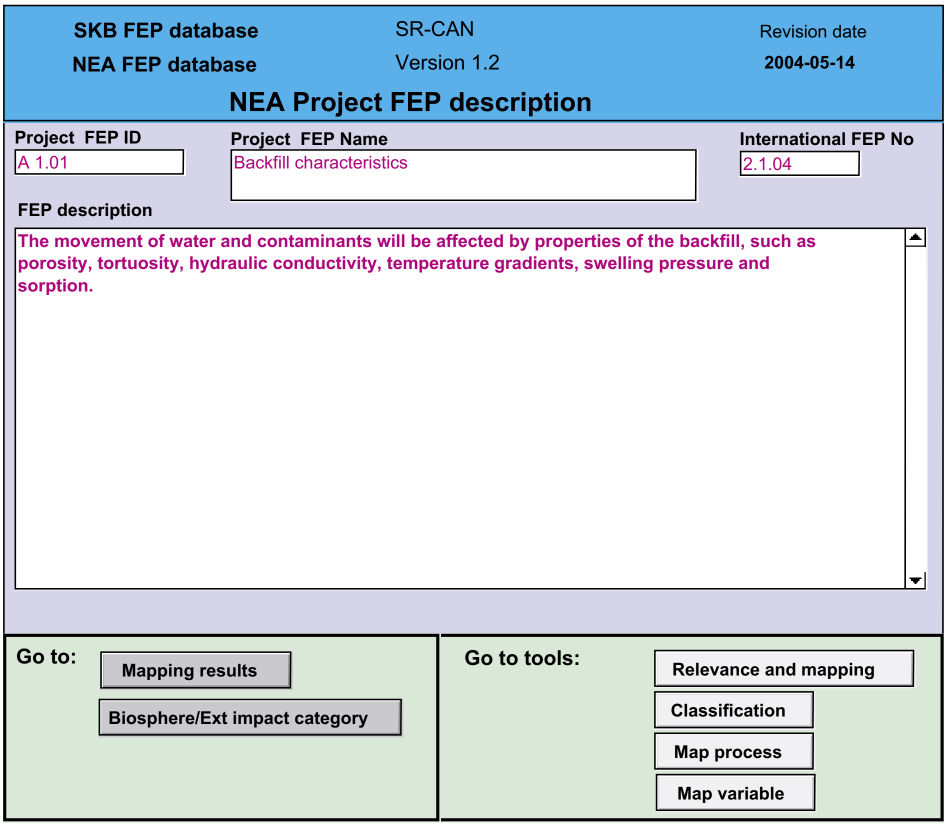

Figure 4-17. Layout showing the description of the NEA project FEP from the register PROFEP in the NEA database.

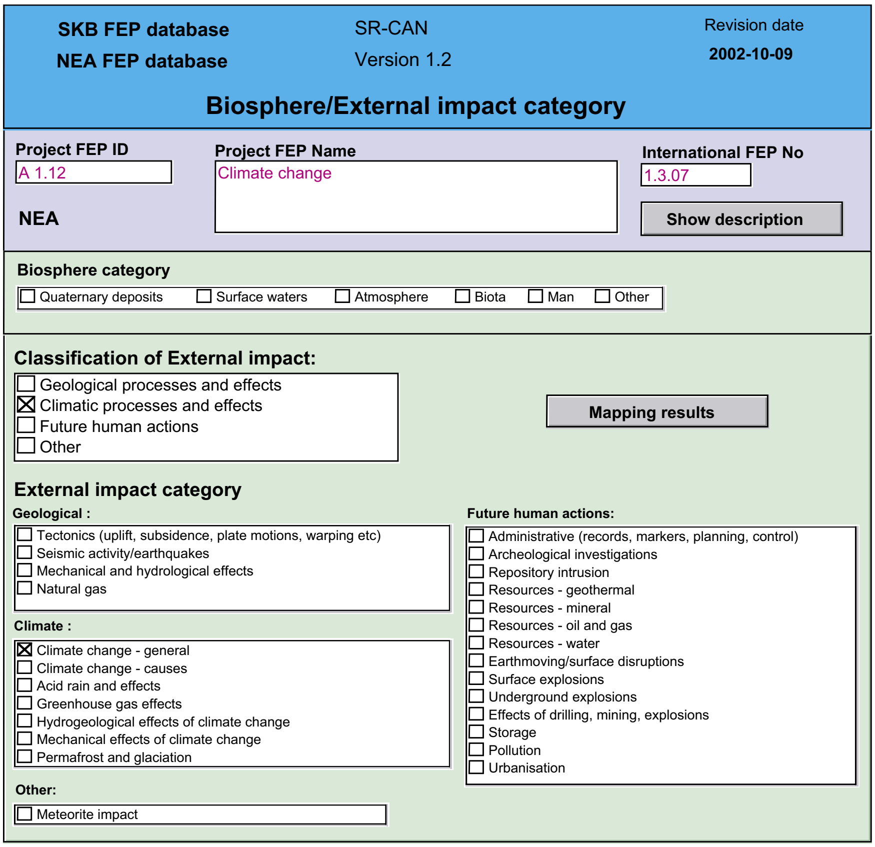

Figure 4-18. *Layout displaying the sorting of NEA FEPs into biosphere and external impact categories.*

The SKB processes and variables that are judged to fit the whole or parts of the NEA FEP description are shown in the lower half of the layout "Relevance and mapping results" (Figure 4-16). The processes are identified by their process number (first digit relates to the system component) and process name in the SR-Can process register. The variables are identified by the system component and variable number as well as by their variable name in the SR-Can variable register. To the right of each process and variable there is a button for showing a field named "mapping comments". This is a field that belongs to the actual process or variable record in the process or variable register. Suggested modifications and additions to the process or variable descriptions that have arisen during the mapping process are compiled in this field.

NEA project FEPs that were assessed to be related to the initial state of the different system components were compiled into a category named "Initial state general" and added to the variable register of the SR-Can database. These FEPs were at a later stage further classified as belonging to a particular variable, or as "Design deviations" (IS Design deviations in mapping file, layout Relevance and mapping results) or as "Mishaps" (IS Mishaps in mapping file, layout Relevance and mapping results) or left as "Initial state general". These different classes of "Initial states" are further addressed in the section describing the variable/initial state register.

4.3.4 Matrix mapping file

The content of the SKB interaction matrices has been mapped onto the registers in the SKB FEP database. This mapping is in essence similar to the mapping reported in /Pers et al, 1999/ with the exception of a few revisions and the addition of mapping to variables and initial states, which were not done in Pers et al. The result of the audit of the content in the interaction matrices is shown in a separate register. This matrix mapping register is entered from the SR-Can start menu (Figure 4-14) via the square "Matrix mapping".

The layout entered shows the result of the audit (see Figure 4-19). In the upper part of the layout the interaction matrix and the identification (number and name) of the interaction in the matrix are given. The mapping register contains one record for each interaction in the three matrices "Near field", "Far field" and "Buffer".

In the next section of the layout the relevance and classification of the interaction is displayed. The different categories for classification of the interaction are the same as those used in the audit against the NEA Project FEPs.

For all matrix interactions assessed as belonging to a process or a variable/initial state, the relevant processes and/or variables/initial states in the process or variable registers are displayed in the lower part of the layout showing the mapping results (Figure 4-19). Likewise to the audit against the NEA project FEPs, the audit against the interaction matrices has resulted in mapping comments that are displayed by clicking the button "show" under the heading "Mapping comments" to the right of the process or variable name. These mapping comments are compiled in a matrix mapping comment field in the actual record in the process or variable register. This is further described in Section 4.3.5.

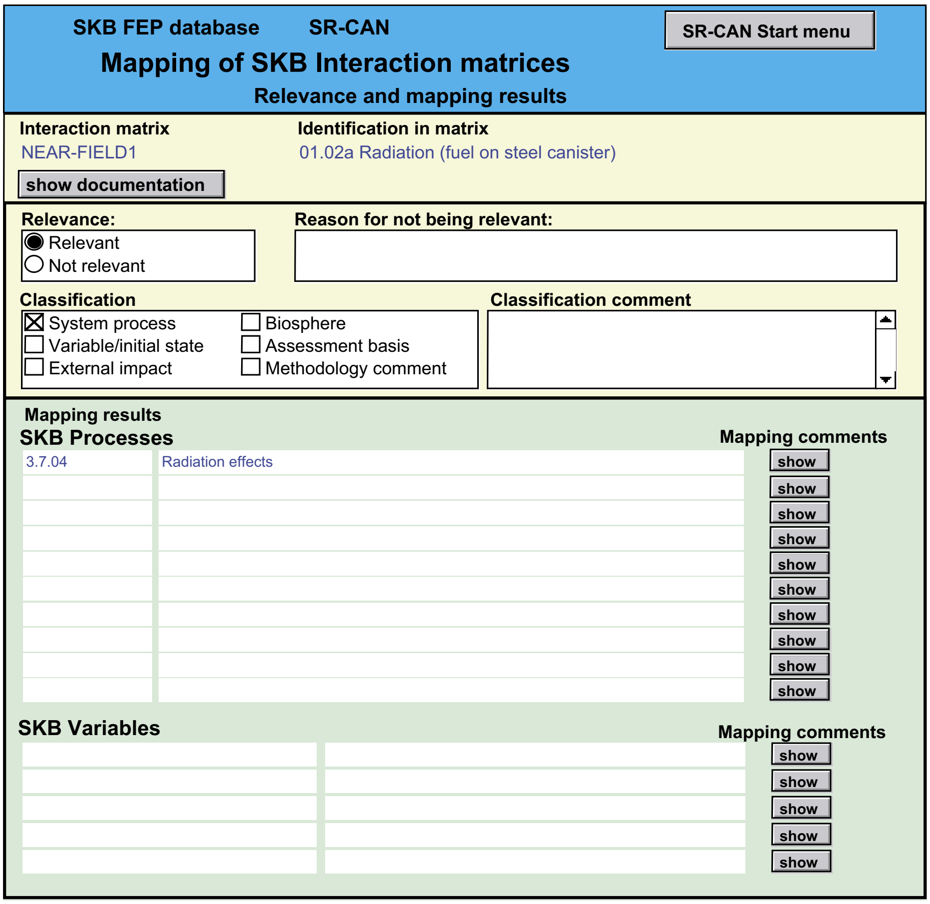

Figure 4-19. Layout in the matrix mapping register showing the results of mapping against the content of the SKB interaction matrices.

4.3.5 Internal EBS and geosphere processes, variables and initial states

The files with SR-Can processes, variables and initial states are structured in a similar way as these files in the SR 97 version. The main menu for this part of the database is entered via the square "EBS and Geosphere Processes, Variables, Initial states" in the SR-Can start menu (Figure 4-14). From this main menu it is possible to enter the process register or the variable register by clicking the appropriate system component button (see Figure 4-20).

One difference in the system definition compared to SR 97 is the higher resolution in the separation of components of the system. This means that the system description no longer is one dimensional in the sense that a system component only has one inner and one outer neighbour. This dimensionality affects the automatic generation of process diagrams. In the interim version of the database, the part of the SR-Can database that relates to the generation of process diagrams has not been adapted to the higher resolution in the system description. However, the option to do it is there and the coming work with the process description in SR-Can will reveal the need and format for these diagrams.

Process descriptions

Likewise to the SR 97 version of the process register, the buttons under heading Process Descriptions in the main menu (Figure 4-20) will display a list of processes for the selected system component and the description of a process is entered via the button "Description". The layouts showing the process are also essentially the same as those showing the process descriptions in the SR 97 version (see Figure 4-21). Some modifications have been made to the headings of the description. Another difference is that it is possible to display the result of the audit against the NEA project FEPs and the SR 97 Interaction matrices. This information is accessed via the buttons "NEA Project FEPs version 1.2" and "Interaction matrix" under the heading "Mapping" in the different layouts for showing process descriptions. This is further described in the next section.

The interim version of the SR-Can database contains no text at all under the different headings of the process description since the work with updating these descriptions still is in progress.

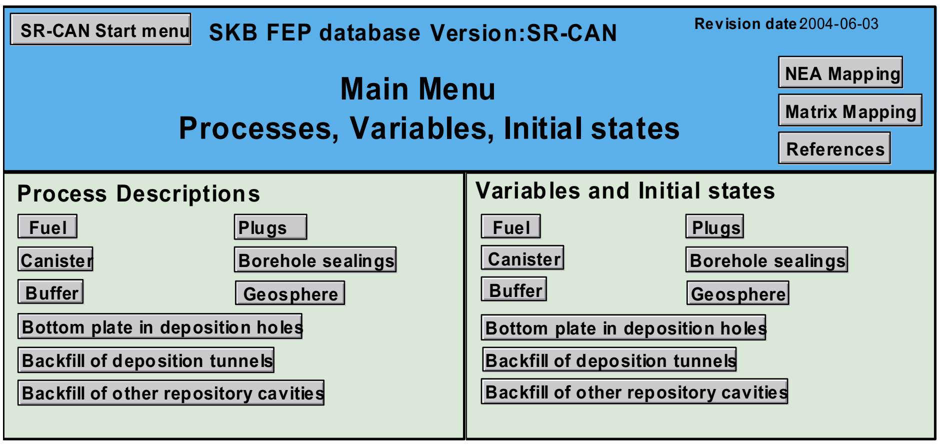

Figure 4-20. *Main menu for SR-Can processes, variables and initial states.*

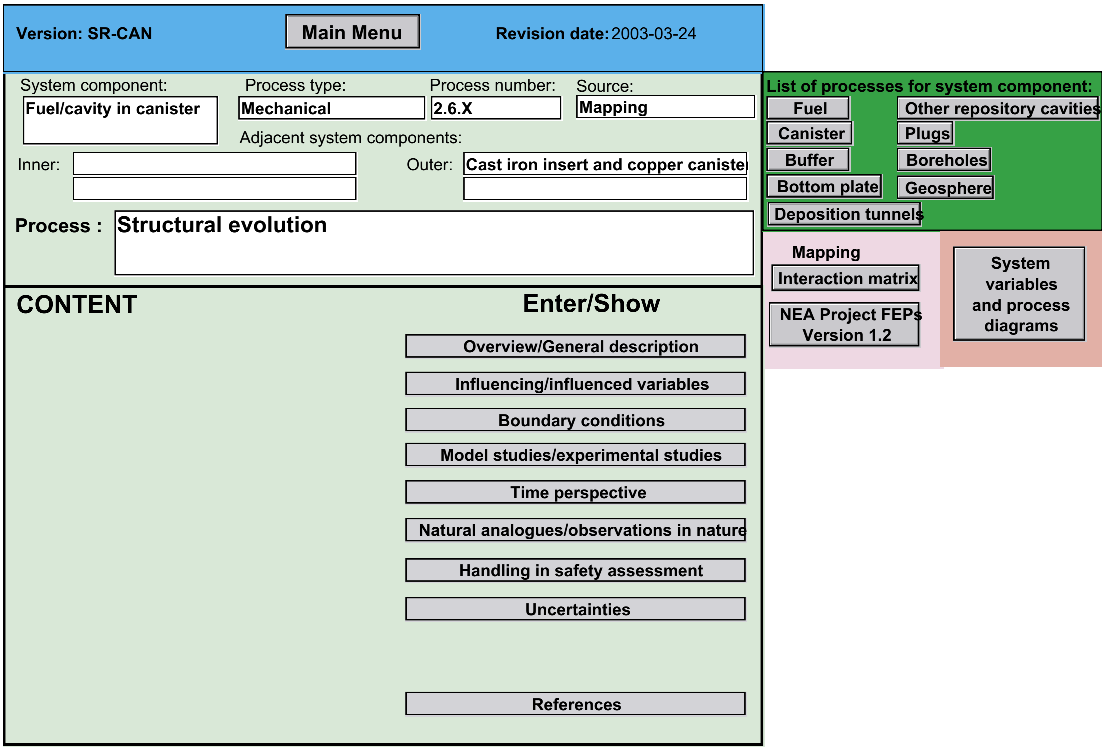

Figure 4-21. Layout for showing the content of a process description and for access to descriptions under different headings.

Processes – Audit/mapping results

The results of the audit of the content of the SR 97 version of the database against the NEA project FEPs and the SKB Interaction matrices are displayed via the buttons "NEA Project FEPs Version 1.2" and "Interaction matrix", respectively (see Figure 4-21). The layout entered via the button "NEA Project FEPs" is shown in Figure 4-22. Comments from the auditing work that are related to the actual process are compiled in a mapping field that is displayed under the heading NEA Mapping comments. A list of all NEA project FEPs that have been mapped to this process is shown under the heading Mapped NEA FEPs. This list appears in red print in order to display that this information is automatically compiled from the NEA mapping register. By clicking the button "show" to the right of the name of the NEA FEP, the NEA mapping register is entered (via a script) and the layout showing the NEA description of the FEP is displayed (see Figure 4-23). From this layout it is possible to view the information compiled in this NEA FEP record in the NEA mapping file via the various buttons appearing in the layout. In the grey field to the left on the screen, two buttons are present under a heading Manus: (see Figure 4-23). By pressing the upper button "Fortsätt", the script will continue and bring back on the screen the departed process record in the process register. The other button "Avbryt" will cancel the script and return to the process register is more complicated, but possible via the buttons "Mapping results" and "SR Can start menu". The script buttons will appear on any layout entered in the NEA mapping register as long as the script is not cancelled by pressing the button "Avbryt".

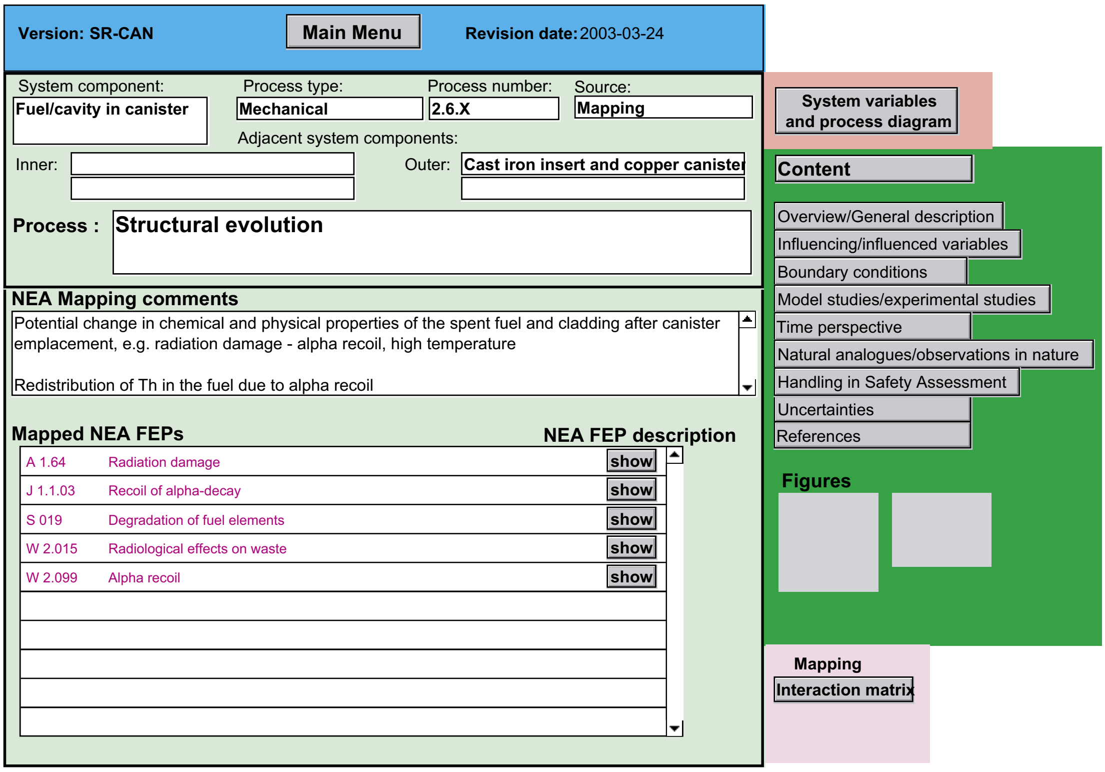

__Figure 4-22.__ Layout showing process-related results of audit against the NEA project FEPs.

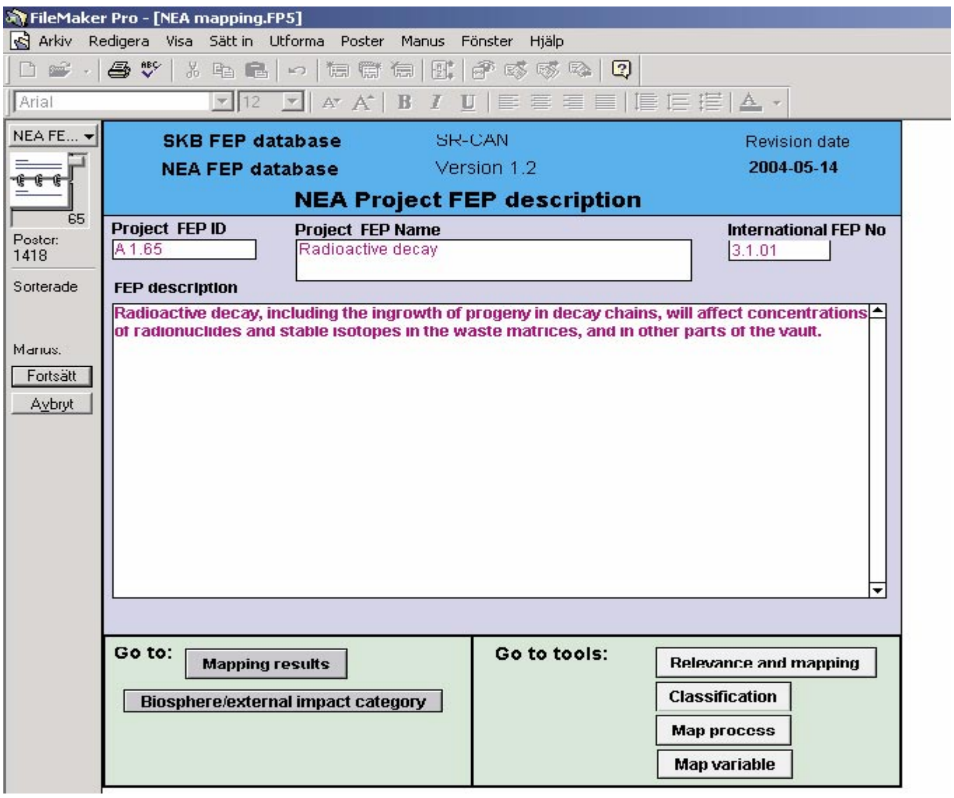

__Figure 4-23.__ Screen print of the layout in the NEA mapping register entered from the mapping layout in the Process register via the button "show" NEA FEP description.

The mapping comments compiled during the audit against the interaction matrix documentation are displayed via the button "Interaction matrix" under the heading Mapping. A layout similar to that accessed via the NEA FEPs mapping button will appear on the screen (Figure 4-24). This layout shows a list of all interactions in the matrices mapped to the actual process and comments compiled during the audit. The list of interactions appears in blue print in order to display that this information is automatically compiled from the matrix mapping register. Also here a script is activated when the button "show", appearing to the right of an interaction name, is pressed and the corresponding interaction record in the matrix mapping register is entered. In order to return to the process record in the process register the script is continued by pressing the button "Fortsätt".

These two layouts displaying the results of the audits show all NEA FEPs and all interactions in the SKB interaction matrices that have been mapped to a specific process in the process register, while the NEA and matrix mapping registers show all processes that a specific NEA project FEP or a specific interaction in an interaction matrix have been mapped to.

Variables/Initial states

Likewise to the SR 97 version of the variable register, pressing a button under the heading "Variables and Initial states" in the main menu (Figure 4-20) will display a list of variables for the selected system component. In the Sr-Can version, this list also contains records that have been added for capturing features and events that can affect the initial state of the system components. These initial state categories are resulting from the audit against the NEA project FEPs and the SKB interaction matrices.

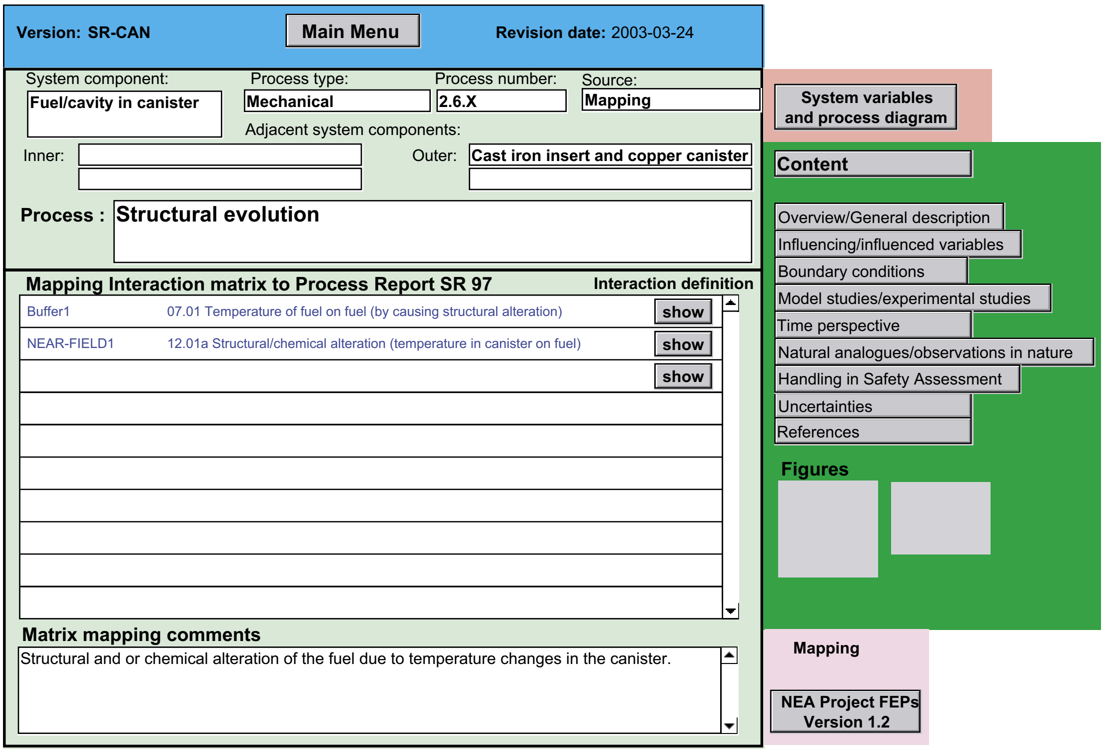

Figure 4-24. *Layout showing process-related results of audit against the SKB Interaction matrices.*

The layouts showing the variable/initial state definitions in the SR-Can version of the database are essentially the same as the corresponding layouts in the SR 97 version with the exception that the records in the SR-Can version also contain the result of the audit against the NEA project FEPs and the SR 97 Interaction matrices. This information is accessed via the buttons "NEA Project FEPs version 1.2" and "Interaction matrix" under the heading Mapping in the layouts showing variable descriptions, i.e. by the same procedure as displaying the audit result in the process register. The layouts displaying the audit results are shown in Figure 4-25 and Figure 4-26.

By clicking the button "show" to the right of the NEA FEP name (Figure 4-25) or the interaction name Figure 4-26) a script is activated that displays on the screen the NEA FEP description in the NEA mapping register or the interaction definition in the matrix mapping register, i.e. a script with functions identical to the script in the process register.

These two layouts displaying the mapping results show all NEA FEPs and all interactions in the SKB interaction matrices that have been mapped to a specific variable or initial state record in the variable register, while the NEA and matrix mapping registers show all variables/initial states that a specific NEA project FEP or a specific interaction in an interaction matrix have been mapped to.

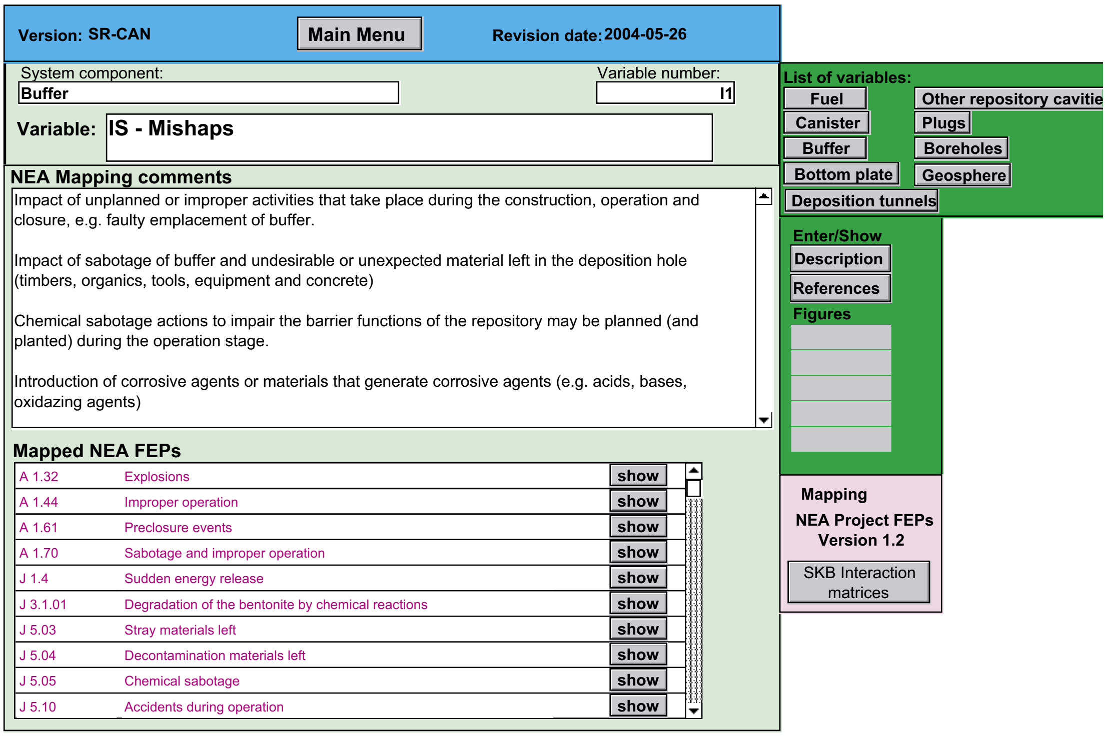

Figure 4-25. Layout showing results of audit against NEA project FEPs, variable/initial state related.

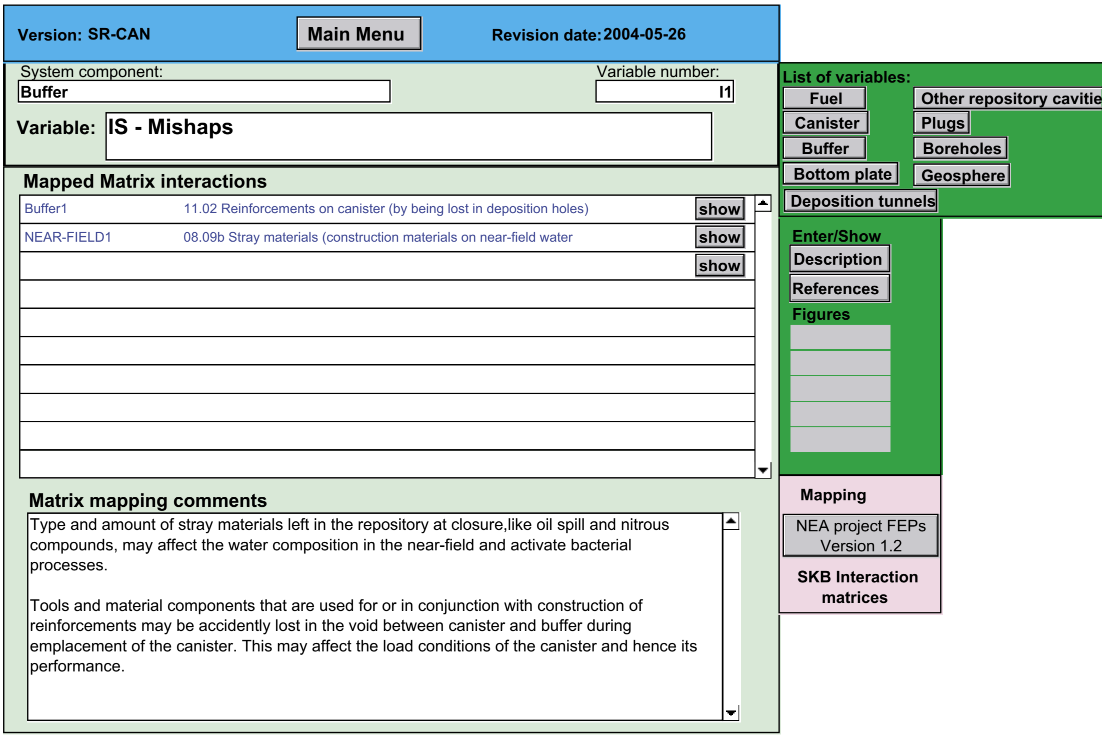

Figure 4-26. *Layout showing results of audit against SKB interaction matrices, variable/initial state related.*

4.3.6 Biosphere FEPs

The interim version of the SR-Can database contains no biosphere processes on the same format as processes for the engineered barriers and the geosphere, since the SR 97 process report does not contain any biosphere processes. However, all NEA FEPs and matrix interactions that, during the audit, were classified as belonging to the biosphere can be viewed via the square "Biosphere FEPs" in the SR-Can start menu (Figure 4-14). The layout entered is shown in Figure 4-27. Via the buttons "List all NEA FEPs and "List Matrix Interactions", all NEA FEPs and matrix interactions sorted to the biosphere are listed. Biosphere FEPs in the NEA database were also further sorted into categories and this sorting is displayed via the button "List NEA FEPs" that is available for each category. The layout entered via this action is shown in Figure 4-28. Here the actual NEA FEPs are listed together with comments documented during the audit. The buttons "show" in this layout as well as in the layouts showing all NEA FEPs and matrix interactions activates a script that displays on the screen the NEA FEP description in the NEA mapping register or the interaction definition in the matrix mapping register, i.e. a script with functions identical to the script in the process register.

It should be noted that the sorting of NEA FEPs into categories of the biosphere is tentative and further processing of this part of the database will be made in conjunction with the development of process descriptions for the biosphere system.

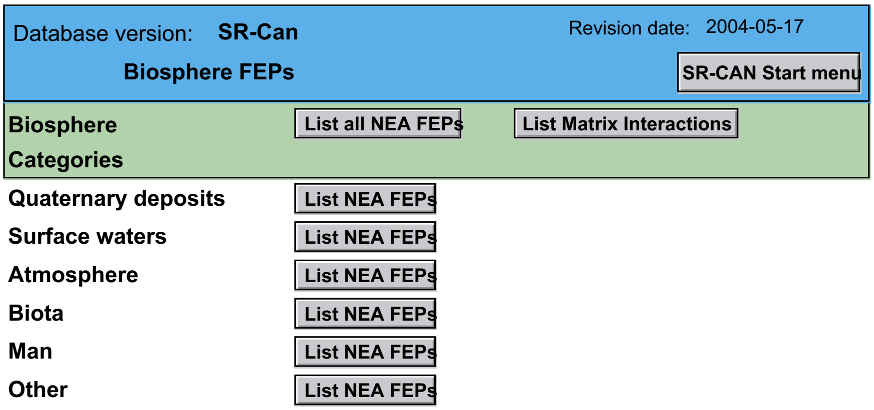

Figure 4-27. Primary layout in the Biosphere FEPs register.

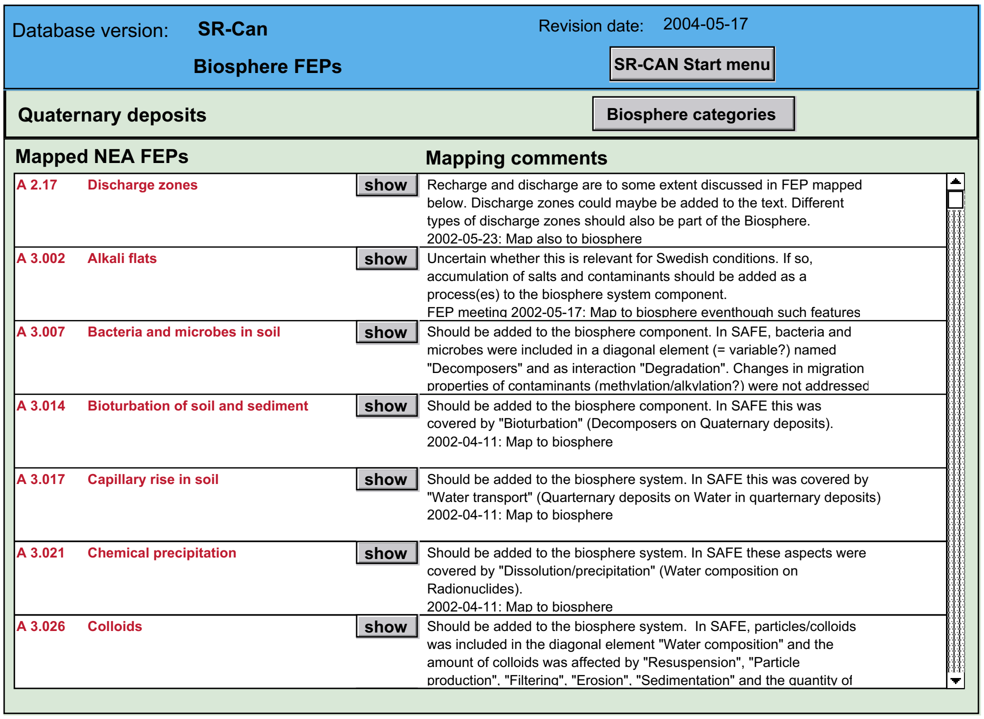

Figure 4-28. Layout in the Biosphere FEPs register listing NEA FEPs sorted to sub-groups or categories of the Biosphere

4.3.7 External factors

The SR-Can database contains a register for compilation of NEA FEPs classified as External Factors and for documentation of the processing of these FEPs in the scenario selection procedure. The documentation part is not implemented in the interim version of the SR-Can database.

The register for External Factors is accessed via the square “External factors” in the SR-Can start menu (Figure 4-14). The layout entered is shown in Figure 4-29. By pressing the button “List” after a category name a list of the groups defined for each category (see Table 2-2) is displayed. Return to the layout showing the main categories is obtained via a button “Content categories”.

All NEA project FEPs sorted to a specific group in the selected main category of external impact FEPs are displayed when clicking the button “show” after the name of the group. An example is shown in Figure 4-30, where all NEA FEPs sorted to the group Tectonics in the category Geological processes and effects are given. The description of each NEA FEP can be viewed by clicking the button “show”. This activates a script with functions identical to the script in the process register.

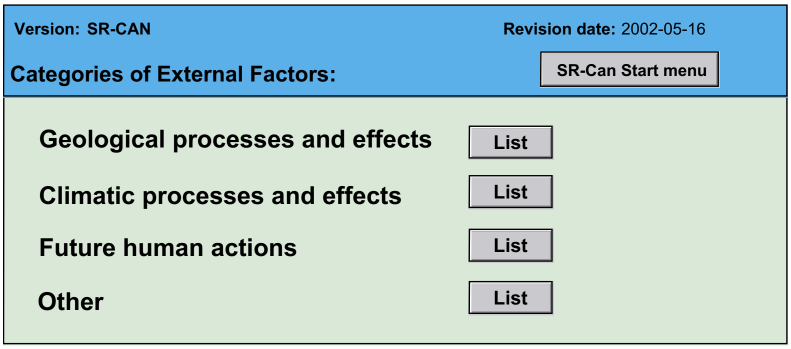

Figure 4-29. *Layout in the register for External Factors that is entered from the SR-Can start menu.*

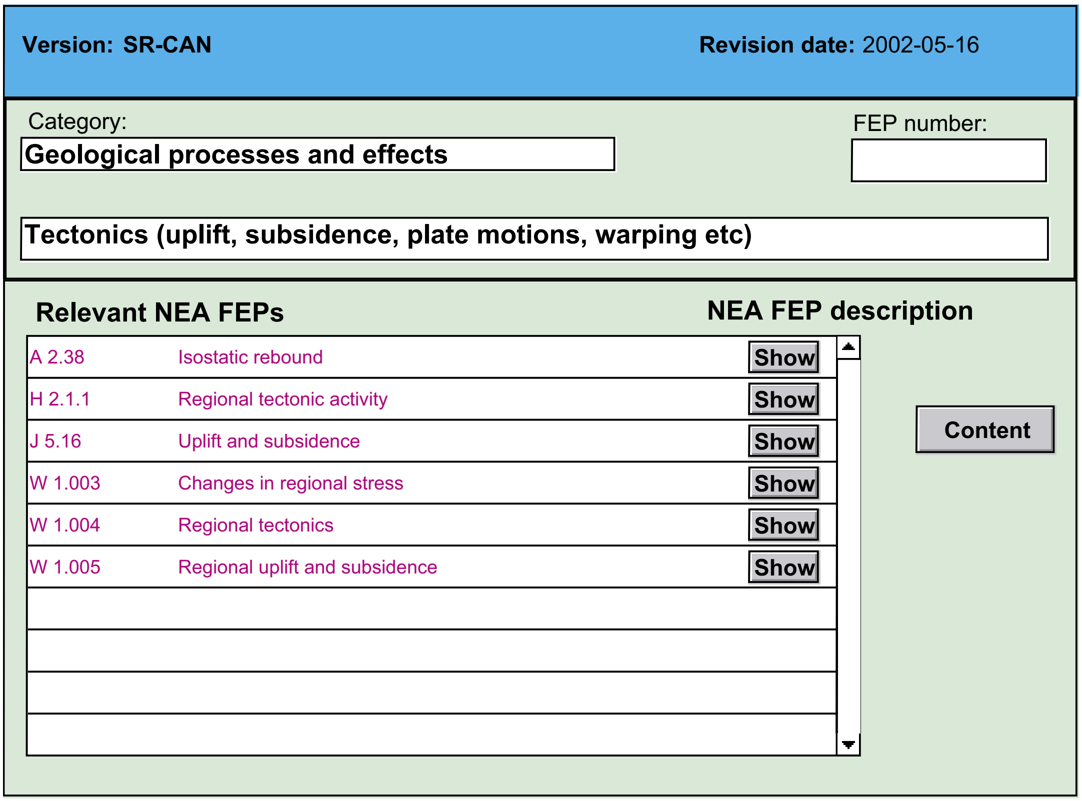

Figure 4-30. *Layout showing NEA FEPs sorted into the group Tectonics in the category Geological processes and effects.*

4.3.8 Methodology issues

NEA FEPs and Matrix interactions classified to the groups "Assessment basis comments" and "General methodology comments and remarks" can be viewed via the square "Methodology issues" in the SR-Can start menu (Figure 4-14). Lists of NEA FEPs and Matrix interactions are accessed via the buttons "List NEA FEPs" and "List matrix interactions" in the first layout entered from the SR-Can start menu. An example is given in Figure 4-31 of NEA FEPs sorted to the group "Assessment basis". Again, the button "show" activates a script that displays the NEA FEP description in the NEA mapping register or the interaction definition in the matrix mapping register, i.e. a script with functions identical to the script in the process register.

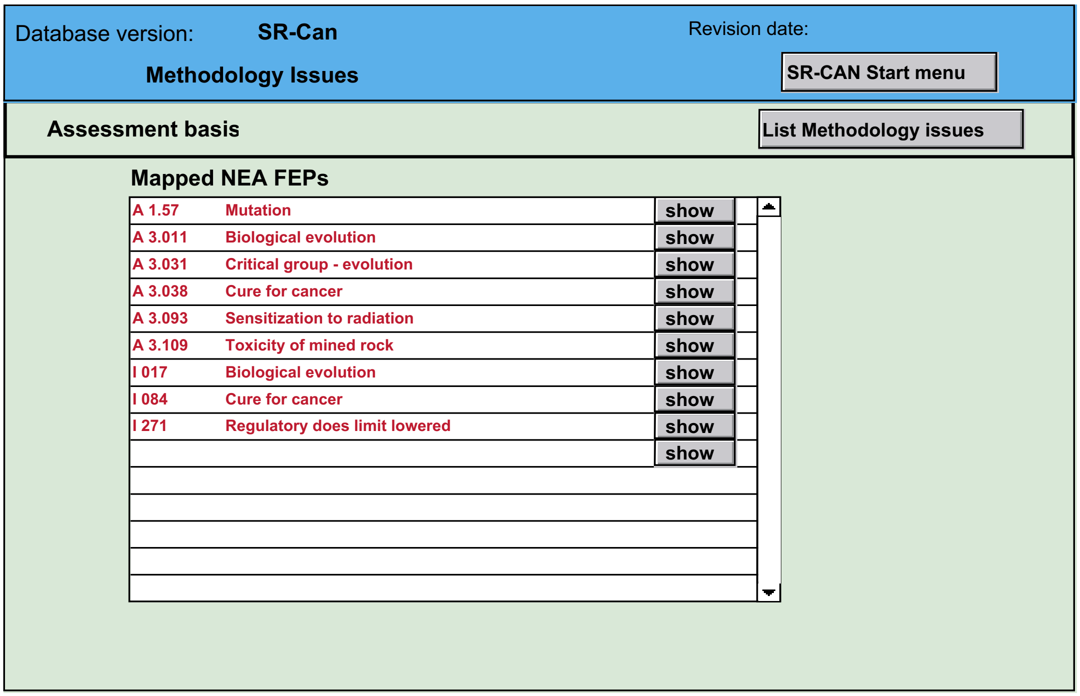

Figure 4-31. *Layout for displaying NEA FEPs sorted to the group "Assessment basis".*

4.3.9 Irrelevant NEA FEPs

All NEA FEPs that were assessed as irrelevant for the SKB system can be displayed via the square "Irrelevant NEA FEPs" in the SR-Can start menu (Figure 4-14). These FEPs are sorted based on the motivation used for assessing the FEP as irrelevant. The first layout entered is shown in Figure 4-32. Via the buttons "List NEA FEPs" the NEA FEPs assessed as irrelevant with the motivation selected are listed and the buttons "show" coupled to the name (heading) of each NEA FEP in the list will display the definition of the FEP in the NEA database.

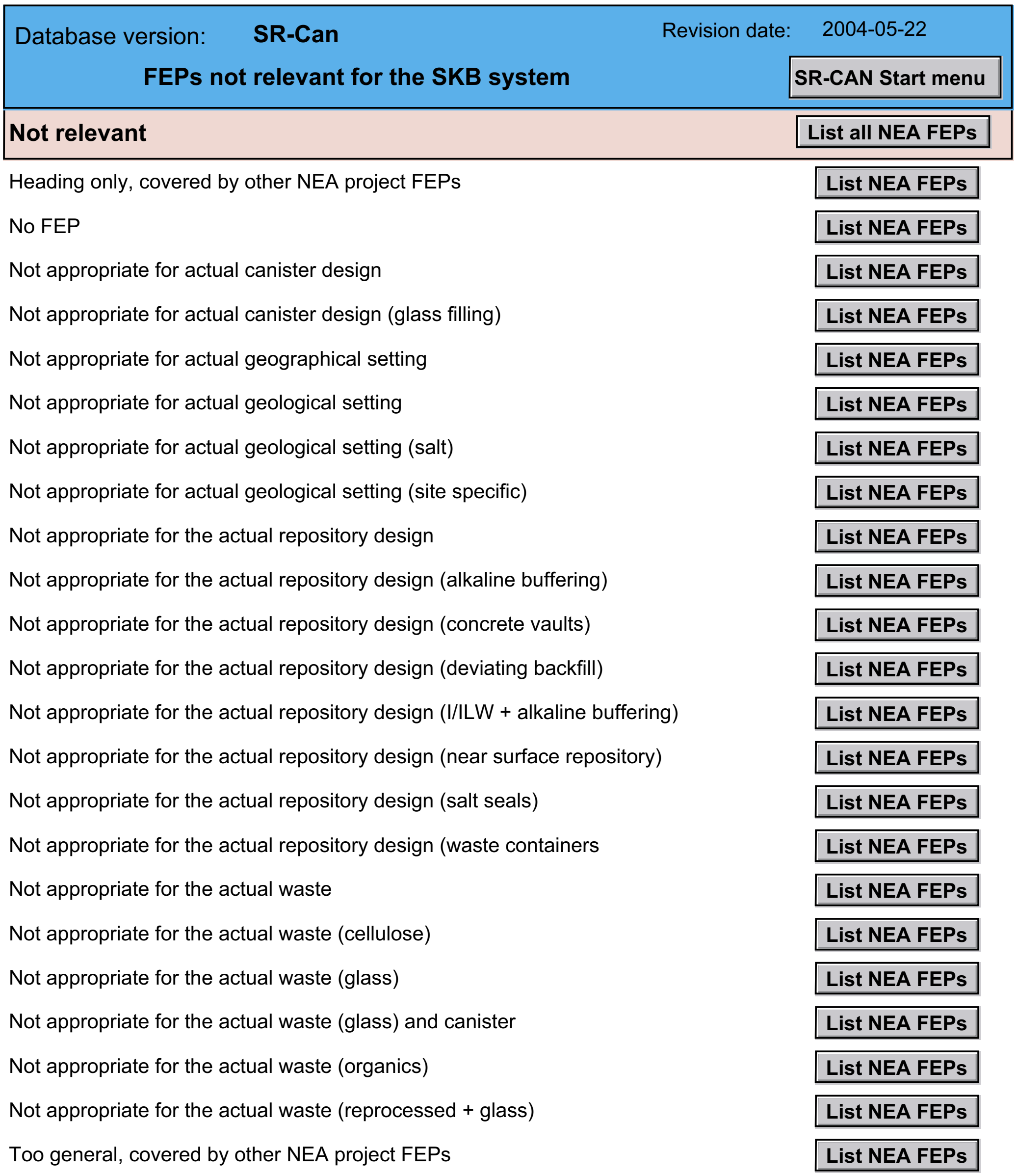

Figure 4-32. *Layout accessed from the SR-Can start menu for showing NEA FEPs assessed as irrelevant.*

5 References

NEA, 1999. Safety assessment of radioactive waste repositories – An international database of features, events and processes. A report on of the NEA working group on development of a Database of Features, Events and Processes Relevant to the Assessment of Post-closure Safety of Radioactive Waste Repositories. Nuclear Agency of the Organisation for Economic Cooperation and Development (OECD/NEA), Paris. Electronic version 1.2 of the NEA FEP Database developed on behalf of the Nuclear Energy Agency by SaSafety Assessment Management Ltd. with support of Quintessa Ltd.

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SKB, 2004b. Interim initial state report for the safety assessment SR-Can. SKB R-04-35, Svensk Kärnbränslehantering AB.

SKB, 2004c. Interim main report of the safety assessment SR-Can. SKB TR-04-11, Svensk Kärnbränslehantering AB.

SKB, 2004d. Interim data report for the safety assessment SR-Can. SKB R-04-34, Svensk Kärnbränslehantering AB.

SKB, 2004e. Preliminary site description Forsmark area – version 1.1. SKB R-04-15, Svensk Kärnbränslehantering AB.

Appendix 1

Tabulation of results of the FEP analysis

Internal Processes

Table 1. List of processes in the process file of the interim SR-Can version of the SKB FEP database. Note that the process list is preliminary for all system components except for the buffer for which an interim version of process descriptions are available /SKB, 2004a/.

System component	Process	Comments/modifications compared to Sr 97
Fuel/cavity in canister	2.3.1 Radioactive decay	
	2.3.2 Radiation attenuation/heat generation	
	2.3.3 Induced fission (criticality)	
	2.4.1 Heat transport	
	2.5.1 Water and gas transport in canister cavity, boiling/ condensation	
	2.6.X Structural evolution	New process
	2.6.1 Thermal expansion/cladding failure	
	2.7.X Microbial processes	New process
	2.7.1 Advection and diffusion	
	2.7.2 Residual gas radiolysis/acid formation	
	2.7.3 Water radiolysis	
	2.7.4 Metal corrosion	
	2.7.5 Fuel dissolution	
	2.7.6 Dissolution of gap inventory	
	2.7.7 Speciation of iron corrosion products	
	2.7.8 Speciation of radionuclides, colloid formation	
	2.7.9 Helium production	
	2.8.1 Radionuclide transport	
Cast iron insert and copper canister	3.3.1 Radiation attenuation/heat generation	
	3.4.1 Heat transport	
	3.6.2 Deformation of cast iron insert	
	3.6.3 Deformation of copper canister from external pressure	
	3.7.1 Corrosion of cast iron insert	
	3.7.2 Galvanic corrosion	
	3.7.3 Stress corrosion cracking of cast iron insert	
	3.7.4 Radiation effects	
	3.7.5 Corrosion of copper canister	
	3.7.6 Stress corrosion cracking	
	3.8 Radionuclide transport	
Buffer	4.3.1 Radiation attenuation/heat generation	
	4.4.1 Heat transport	
	4.4.2 Freezing	New process
	4.5.1 Water uptake and transport under unsaturated conditions	

System component	Process	Comments/modifications compared to Sr 97
	4.5.2 Water transport under saturated conditions	
	4.5.3 Gas transport/dissolution	
	4.5.4 Piping/erosion	New process
	4.6.1 Swelling/Mass redistribution	Extended process
	4.6.2 Liquefaction	New process
	4.7.3 Cementation	
	4.7.4 Advection	Extended to include RN
	4.7.5 Diffusion	Extended to include RN
	4.7.6 Colloid transport	
	4.7.7 Sorption (including ion-exchange)	Extended to include RN
	4.7.8 Alteration of impurities	
	4.7.9 Aqueous speciation and reactions	New process
	4.7.10 Osmosis	New process
	4.7.11 Montmorillonite transformation	
	4.7.12 Colloid release/erosion	
	4.7.13 Radiation-induced transformations	
	4.7.14 Radiolysis of porewater	
	4.7.15 Microbial processes	
	4.7.16 Speciation of radionuclides	
	4.8.1 Transport of radionuclides in water phase	Modified process
	4.8.2 Transport of radionuclides in gas phase	New process
Bottom plate in deposition hole		New system component
	5.4.1 Heat transport	
	5.5.2 Water transport under saturated conditions	
	5.6.1 Mechanical degradation of inorganic engineering materials	New process. To be combined with 5.7.3?
	5.7.3 Decomposition of inorganic engineering material	Concrete and copper
	5.7.5 Difffusion	
	5.7.7 Sorption (including ion-exchange)	
	5.7.13 Radiation effects	
	5.8.1 Transport of radionuclides in water phase	
Backfill of deposition tunnels	6.4.1 Heat transport	In analogy with buffer
	6.4.2 Freezing	In analogy with buffer
	6.5.1 Water uptake and transport under unsaturated conditions	In analogy with buffer
	6.5.2 Water transport under saturated conditions	In analogy with buffer
	6.5.3 Gas transport/dissolution	In analogy with buffer
	6.5.4 Piping/erosion	In analogy with buffer
	6.6.1 Swelling/Mass redistribution	In analogy with buffer
	6.6.2 Liquefaction	In analogy with buffer
	6.6.3 Mechanical degradation of inorganic engineering materials	Move to new system comp. for rock reinforcements?
	6.6.5 Mechanical interaction backfill/near-field rock	Combine with 6.6.1?
	6.6.6 Thermal expansion	Combine with 6.6.1?
	6.7.3 Decomposition of inorganic engineering materials	See 6.6.3
	6.7.4 Advection	In analogy with buffer
	6.7.5 Diffusion	In analogy with buffer
	6.7.6 Colloid formation and transport	In analogy with buffer

System component	Process	Comments/modifications compared to Sr 97
	6.7.7 Sorption (including ion-exchange)	In analogy with buffer
	6.7.8 Alteration of impurities	In analogy with buffer
	6.7.9 Aqueous speciation and reactions	In analogy with buffer
	6.7.10 Osmosis	In analogy with buffer
	6.7.11 Montmorillonite transformation	In analogy with buffer
	6.7.12 Colloid release/erosion	In analogy with buffer
	6.7.13 Radiation-induced transformations	Relevant for backfill?
	6.7.15 Microbial processes	In analogy with buffer
	6.7.16 Speciation of radionuclides	In analogy with buffer
	6.8.1 Transport of radionuclides in water phase	In analogy with buffer
	6.8.2 Transport of radionuclides in gas phase	In analogy with buffer
Backfill of other repository cavities	The same processes as for backfill of deposition tunnels except Radiation-induced transformations. Processes numbered from 7.4.1 Heat transport to 7.8.2 Transport of radionuclides in gas phase,	New system component. Processes in analogy with backfill of deposition tunnels
Plugs	8.4.1 Heat transport	Relevant?
	8.5.2 Water transport under saturated conditions	Relevant?
	8.5.3 Gas transport/dissolution	Relevant?
	8.6.3 Mechanical degradation of inorganic engineering materials	Including freezing?
	8.7.3 Decomposition of inorganic engineering materials	
	8.7.5 Diffusion	
	8.7.7 Sorption (including ion-exchange)	
	8.7.15 Microbial processes	
Borehole sealings		New system component
	9.4.1 Heat transport	Relevant?
	9.4.2 Freezing	
	9.5.2 Water transport under saturated conditions	
	9.5.3 Gas transport/dissolution	Relevant?
	9.6.3 Mechanical degradation of inorganic engineering materials	Concrete, copper etc
	9.7.2 Advection	
	9.7.3 Decomposition of inorganic engineering materials	Concrete, copper etc
	9.7.5 Diffusion	
	9.7.7 Sorption (including ion-exchange)	
	9.7.8 Alteration of impurities	Bentonite seals
	9.7.11 Montmorillonite transformation	Bentonite seals
	9.7.15 Microbial processes	Relevant?
	9.8.1 Transport of radionuclides in water phase	
	9.8.2 Transport of radionuclides in gas phase	
Geosphere	10.4.1 Heat transport	
	10.5.1 Groundwater flow	
	10.5.2 Gas flow/dissolution	
	10.6.X Surface erosion	New process
	10.6.Y Erosion/sedimentation in fractures	New process
	10.6.Z Rock mechanics alteration during construction/ operation	New process
	10.6.2 Movements in intact rock	

System component	Process	Comments/modifications compared to Sr 97
	10.6.3 Thermal movement	
	10.6.4 Reactivation – Movement along existing fractures	
	10.6.5 Fracturing	
	10.6.6 Time dependent deformations	
	10.7.X Radiation effects (rock and grout)	New process
	10.7.Y Earth currents	New process
	10.7.Z Chemical alterations during construction/operation	New process
	10.7.2 Advection/mixing	
	10.7.3 Diffusion	
	10.7.4 Reactions groundwater/rock matrix	
	10.7.5 Dissolution/precipitation of fracture-filling materials	
	10.7.6 Microbial processes	
	10.7.7 Degradation of grout	Renamed process
	10.7.8 Colloid formation	
	10.7.9 Gas formation/dissolution	
	10.7.10 Methane ice formation	
	10.7.11 Salt exclusion	
	10.8.1 Advection and dispersion 10.8.2 Sorption (radionuclides) 10.8.3 Molecular diffusion and matrix diffusion 10.8.4 Colloid transport 10.8.5 Speciation (radionuclides) 10.8.6 Transport in gas phase 10.8.7 Radioactive decay	Revise to follow same structure as in buffer, i.e. combine/move transport and retardation processes and introduce two general processes for radionuclide transport in water and gas phase, respectively?

Initial States

Table 2. General issues related to the initial state of the repository system. Results of FEP analysis.

Factor/Issue	Handling in SR-Can	Notes	NEA FEPs/Interactions
Major mishaps/ accidents like fire, explosions, earth quakes and flooding in encapsulation plant, during transport and repository operation. Possible decontamination following severe mishap Ditto sabotage (chemical, physical etc), improper management	Severe mishaps like fire, explosions, sabotage and severe flooding will be excluded from scenario selection. The reasons for this are i) the probabilities for such events are low and ii) if they occur, this will be known prior to repository sealing so that mitigation measures and assessment of possible effects on long-term safety can be based on the specific real event.	Probabilities will depend on technical solutions and handling procedures. Probabilities can be influenced by the design of these. “Reasonable” mishaps included in main scenario.	A 1.32 Explosions A 1.44 Improper operation A 1.61 Preclosure events A 1.70 Sabotage and improper operation. A 2.23 Explosions A 2.56 Sabotage H 1.2.7 Flammability I 022 Explosions/bombs/ blasting/collisions/ impacts/ vibration J 1.4 Sudden energy release J 4.3.01 Mechanical failure of repository J 5.04 Decontamination materials left J 5.05 Chemical sabotage W 2.027 Gas explosions

Factor/Issue	Handling in SR-Can	Notes	NEA FEPs/Interactions
Effects of phased operation (affects mainly geosphere and the subsequent development of the entire repository); also effects of blasting and underground traffic on completed parts of the repository	Hydro: Transient modelling of open repository part of main scenario Effects of excavation on completed parts need to be mentioned in SR-Can and analysed in SR-Site	Mention in main scenario	A 1.61 Preclosure events A 2.01 Blasting and vibration I 022 Explosions/bombs/ blasting/collisions/ impacts/ vibration N 2.2.12 Effects of phased operation Far-field 02.08 Resaturation
General deviation in initial state to be managed: Incomplete closure. Incomplete closure will obviously affect most variables in the engineered barriers and the host rock.	To be considered in scenario selection. Unsealed repository as "Residual scenario" in SKI's General Advice. Assume filled and sealed deposition tunnels. Assume lifetime of seals. Oxidising conditions? Pumped repository? Refilled repository?	Outline incomplete closure scenario in Interim report	A 1.45 Incomplete closure A 2.47 Open boreholes A 2.70 Vault closure (incomplete) I 203 Monitoring shaft (failure to close) J 5.02 Non-sealed repository J 5.09 Unsealed boreholes and/or shafts J 5.39 Postclosure monitoring K 5.25 Exploratory boreholes (sealing) W 2.011 Postclosure monitoring
Unsealed surface based investigation boreholes (mishap) "Poorly sealed" ditto	Include poorly sealed as residual scenario or probabilistically in main scenario depending on basis for assessing sealing. Results gives basis for consequence of unsealed, possibly included as "residual"	Mention in SR-Can Include in SR-Site	A 2.47 Open boreholes I 203 Monitoring shaft (failure to close) J 5.09 Unsealed boreholes and/or shafts J 5.39 Postclosure monitoring K 5.25 Exploratory boreholes (sealing) W 2.011 Postclosure monitoring
Model simplifications of design details (SR-Can) and, at later stages of the programme, of deviations between specified and actual design.	General consideration in deriving an initial state from a given repository design to include all safety relevant features…	Include in FEP db	A 1.56 Monitoring and remedial activities A 1.87 Unmodelled design features
A description of monitoring activities is needed for SR-Can.	Refer to coming report on monitoring R-04-13. Table? Focus on influence on long-term safety.	Mention in SR-Can Interim report. A few deep boreholes open to monitor resaturation after closure? If so, affects early transient hydro analyses? Connected to unsealed boreholes. Possible consequence analyses in SR-Site.	A 1.56 Monitoring and remedial activities J 5.39 Postclosure monitoring W 2.011 Postclosure monitoring

Table 3. System component specific factors/issues related to initial states. Results of the FEP analysis.

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Fuel/cavity in canister			
Initial enrichment, possible Pu enrichment, burn-up, fuel damage (geometry, inventory, material composition, radiation intensity)	Included in IS report.	Check coupling between fuel types and inventories.	J 1.3 Damaged or deviating fuel
Variability in fuel characteristics between canisters (geometry, inventory, material composition, radiation intensity)	Necessary to describe in final SR-Can IS report. To be mentioned in Interim version.		J 1.3 Damaged or deviating fuel K 1.27 Deviant inventory flask W 2.003 Heterogeneity of waste formes
The material composition should include also chemically toxic elements (implying that the list of elements should be complete)	Included in IS report.		A 1.50 Inventory
Cast iron insert and copper canister			
The material composition should include also chemically toxic elements (implying that the list of elements should be complete)	Included in IS Report for copper canister and cast iron insert		A 1.50 Inventory
Welding or material defects (geometry, material composition) E.g. loss of ductility due to impurities in the copper material or bad manufacturing methods or “Cold cracks” due to bad manufacturing methods	Welding defects are critical for the safety case, thus handled in the data report as distribution of minimum copper coverage for main scenario. Welding process QA mishaps to be further discussed. Copper material defects: cracks in top and bottom of ingot need to be discussed, possibly also other defects Cast iron material defects affecting strength: Graphite structure, slag, cavities: “Normal” variations in graphite structure included in probabilistic analyses of strength.		A 1.17 Container failure (early) J 2.3.04 Loss of ductility J 2.3.06 Cracking along welds K 2.22 Mis-sealed canister
Mishandling and breakage during manufacturing, sealing, transport and deposition (input from PSR for each system; PSRs should have considered defined damage criteria for the canister)	Canister very sensitive to mechanical impact at mishaps (dropping)… Need document with description of measures to avoid damages and conclusions about likelihoods.	No consequence calculations??	A 1.17 Container failure (early) J 5.10 Accidents during operation K 1.26 Handling accidents
Random defects despite quality control in manufacturing and sealing	See above		J 2.5.01 Random canister defects – quality control

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
A number of defects related by a common cause despite quality control in manufacturing and sealing	See above		J 2.5.02 Common cause canister defects – quality control
Tools and other materials accidentally lost in the void between canister and buffer (should be buffer variable stray material)	Mishap to be further elaborated.		Buffer 11.02 Reinforcements on canister (by being lost in deposition hole). Near-field 08.03 Mechanical impact (construction materials on copper canister)
Buffer and bottom plate in deposition holes			
Faulty or deviating buffer emplacement caused by e.g. difficulties due to inflow, problems with remote control handling, etc leading to e.g. inhomogeneous buffer and/or reduced density	Included in scenario selection		A 1.33 Faulty buffer emplacement I 029 Buffer (faulty emplacement) K 3.23 Poor emplacement of buffer
Deviations in buffer and structural material (concrete bottom "plate") properties despite quality control	Included in scenario selection		I 062a1 Concrete (incorrect structural design) I 062a2 Concrete (incorrect mix design) I 062b Concrete (incorrect preparation/ emplacement) I 062f Concrete (poor quality – procurement) J 3.1.02 Degradation of bentonite buffer by chemical reactions J 3.2.11 Backfill material deficiences
The material composition should include also chemically toxic elements (implying that the list of elements should be complete)	Included in reference initial state.		A 1.50 Inventory
Spillage of oil, hydraulic fluids or organic solvents, nitrous compounds and common corrosive chemicals should be considered when specifying impurities and stray materials	Included in reference initial state.		I 044 Chelating agents I 071 Corrosive chemicals (in vault) J.5.03 Stray materials left J 5.04 Decontamination materials left K 3.24 Organics/contamination of bentonite K 4.18 Oil or organic fluid spill W 2.068 Organic complexation W 2.069 Organic ligands Near-field 08.09b Stray materials
Tools and other materials accidentally lost in the void between canister and buffer	Should be included in scenario selection		Buffer 11.02 Reinforcements on canister (by being lost in deposition hole). Near-field 08.03 Mechanical impact (construction materials on copper canister)
Backfill of deposition tunnels, plugs (and backfill of other repository cavities)			
Fracturing of deposition tunnel plugs due to heat generation during maturing	Need to consider handling in main scenario and unsealed repository.	Assume no beneficial hydraulic properties at any time? Not handled as process in safety assessment?	W 2.073 Concrete hydration

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
The material composition should include also chemically toxic elements (implying that the list of elements should be complete)	Included in reference initial state.		A 1.50 Inventory
Faulty or deviating backfill emplacement due to e.g. difficulties due to inflow, etc leading to e.g. inhomogeneous backfill	Included in scenario selection		I 011b Backfill (faulty emplacement)
Spillage of oil, hydraulic fluids or organic solvents, nitrous compounds and common corrosive chemicals should be considered when specifying impurities and stray materials	Included in reference initial state.		I 044 Chelating agents I 071 Corrosive chemicals (in vault) J.5.03 Stray materials left J 5.04 Decontamination materials left K 3.24 Organics/contamination of bentonite K 4.18 Oil or organic fluid spill W 2.068 Organic complexation W 2.069 Organic ligands Near-field 08.09b Stray materials
Deviations in backfill properties despite quality control	Included in scenario selection		I 062a1 Concrete (incorrect structural design) I 062a2 Concrete (incorrect mix design) I 062b Concrete (incorrect preparation/ emplacement) I 062f Concrete (poor quality – procurement) J 3.2.11 Backfill material deficiences
Degradation/corrosion of reinforcements during operation should be considered when specifying the initial state (corrosion products should be included in structural and stray materials).	Included in reference initial state.	No detailed analyses in SR-Can	J 4.2.10 Chemical effects of rock reinforcements
Injection boreholes and grouting practices in deposition tunnels	Included as construction materials in reference initial state.	If design suggests grouting needed in parts of deposition tunnels, the hydraulic consequences should be explored in main scenario.	K S1.2 Waste emplacement and repository
Geosphere (and boreholes)			
Geometry and locations of known and possibly undetected boreholes – surface and underground. This may affect the permeability of the rock.	Existing boreholes at current stage of investigations included in SDM. Consequence of possibly poorly sealed holes to be included in scenario selection.		W 2.038 Invetsigation boreholes W 3.033 Flow through undetected boreholes
Composition of grout (other structural/stray materials) injected/located in fractures in the rock	In principle part of geosphere, but specified as "structural and stray materials" in deposition tunnel backfill		K S1.2 Waste emplacement and repository

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Intrusion of deep saline water due to atmospheric pressure in the repository during excavation/operation.	Included in main scenario		K 5.11 Intrusion of saline water K 6.11 Intrusion of saline water S 018 Deep saline water intrusion
Rock fallout during excavation and operation which will alter the repository geometry and the properties of the near field rock.	Included in reference initial state (deposition tunnel geometry)		A 1.89 Vault geometry S 032 Excavation effects on nearby rock

External Factors

Table 4. Climate processes and effects. Results of the FEP analysis.

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Climate change – general	Part of main scenario, including also uncertainties and sensitivities		A 1.12, A 2.07, I 049, W 1.061 Climate change K 10.04 Future climatic conditions
Permafrost and glaciation	See above		A 1.38, A 2.30, A 3.057, J 5.42 S 047, W 1.062 Glaciation J 5.17, K 10.13, S 059, W 1.063 Permafrost A 3.024 Climate change H 3.1.2 Climate change: natural H 3.1.4 Intensification of natural climate change J 6.10 No ice age K 10.05 Tundra climate K 10.06 Glacial climate K 10.16 Ice sheet effects
Hydrogeological effects of climate change	See above		A 2.19 Drought A 2.25 Flood A 2.59 Sea level change A 3.043 Dust storms and desertification H 3.1.1 Climate change: Human induced H 3.1.2 Climate change: Natural H 3.1.3 Exit from glacial/interglacial cycling I 266 Sea level (rising) J 5.31 Change in sealevel J 5.32 Desert and unsaturation K 10.16 Ice sheet effects S 081 Sea level changes W 1.056 Changes in groundwater recharge and discharge W 1.068 Sea level changes
Mechanical effects of climate change	See above		H 2.1.7 Faulting/fracturing J 4.2.01 Mechanical failure of repository J 4.2.06 Faulting K 10.16 Ice sheet effects S 036 Faulting

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Climate change – causes	Basis for defining main scenario – including greenhouse effect		A 2.40 Magnetic poles (reversal) A 2.48 Ozone layer A 3.051 Flipping of earth's magnetic poles A 3.078 Ozone layer failure J 5.20 Changes of the magnetic field W 3.049 Damage to the ozone layer
Greenhouse gas effects	Included in main scenario		A 2.31, A 3.059, K 10.10 Greenhouse effect K 10.03 Seasonality of climate K 10.07 Warmer climate – arid K 10.08 Warmer climate – seasonal humid K 10.09 Warmer climate – equable humid K 11.09 Human-induced climate change W 3.047 Greenhouse gas effects
Acid rain and effects	Acidification handled in biosphere studies. Geosphere process "erosion/weathering" should consider also chemical aspects.	Human induced acid rain handled as FHA FEP pollution.	A 3.001, I 001, W 3.048 Acid rain J 7.08 Altered surface water chemistry by humans

Table 5. Geological processes and effects. Results of the FEP analysis.

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Tectonics (uplift, subsidence, plate motions, warping etc)	Part of main scenario		A 2.38 Isostatic rebound H 2.1.1 Regional tectonic activity J 5.16 Uplift and subsidence W 1.003 Changes in regional stress W 1.004 Regional tectonics W 1.005 Regional uplift and subsidence
Seismic activity/ earthquakes	Part of main scenario		A 1.29, A 2.21, A 3.045, J 5.15, Earthquakes H 2.1.6 Seismicity I 100 Seismic events K 9.05, W 1.012 Seismic activity
Mechanical and hydrological effects	Part of main scenario		A 2.24, J 4.2.06, S 036 Faulting J 4.2.01 Mechanical failure of repository K 5.18 Hydraulic gradient changes K 9.06 Stress changes – hydrogeological effects W 1.008 Formation of fractures W 1.010 Formation of new faults W 1.011 Fault movement W 1.031 Hydrological response to earthquakes
Natural gas	Part of main scenario		J 5.43 Methane intrusion W 1.032 Natural gas intrusion

Table 6. Future Human Actions. Results of FEP analysis.

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Repository intrusion	Included in scenario selection.		A 1.49 Intrusion (human) A 1.69 Retrievability A 2.05 Boreholes – exploration A 2.37 Intrusion (mines) A 3.070 Intrusion (deliberate) A 3.071 Intrusion (inadvertent) H 5.2.2 Deliberate intrusion H 5.2.3 Malicious intrusion H 5.2.4 Accidental intrusion I 167 Intrusion (human/deliberate) I 169 Intrusion (human/inadvertent) I 253 Retrievability J 5.33 Waste retrieval, mining J 5.37 Archeological intrusion K 11.01 Exploratory drilling W 3.012 Deliberate drilling intrusion W 3.018 Deliberate mining intrusion
Resources – mineral	Included in scenario selection.		A 2.46 Mines A 2.61 Solution mining I 200 Minerals (exploration, exploitation) J 5.35 Other future uses of crystalline rock K 11.01 Exploratory drilling K 11.02 Mining activities W 3.002 Potash exploration W 3.008 Other resources W 3.013 Potash mining W 3.014 Other resources W 3.019 Explosions for resource recovery
Resources – oil and gas	Not relevant for site conditions		A 2.05 Boreholes – exploration K 11.01 Exploratory drilling W 3.001, W 3.004 Oil and gas exploration W 3.009 Enhanced oil and gas recovery W 3.011, W 3.029 Hydrocarbon storage W 3.025 Oil and gas extraction W 3.028 Enhanced oil and gas production
Resources – geothermal	Included in scenario selection.		A 3.061 Heat storage in lakes or underground J 5.34 Geothermal energy production K 11.01 Exploratory drilling K 11.03 Geothermal exploitation W 3.007 Geothermal

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Resources – water	Included in scenario selection. Wells included in consequence analyses of main scenario.		A 3.115 Water management projects
			J 5.27 Human induced actions on groundwater recharge
			J 7.07 Human induced changes in surface hydrology
			K 11.06 Water management schemes
			W 3.003 Water resources exploration
			W 3.005 Groundwater exploitation
			W 3.026 Groundwater extraction
Storage	Included in scenario selection.		I 046a Waste management sites adjacent (additive effects of contaminants)
			I 046b Waste management sites adjacent (effects on vault)
			J 5.12 Near storage of other waste
			K 11.04 Liquid waste injection
			W 3.010 Liquid waste disposal
			W 3.016 Construction of underground facilities (for example storage, disposal, accomodation)
Surface explosions	Included in scenario selection.		A 1.32, J 5.38 Explosions
			A 2.02 Bomb blast
			A 2.56 Sabotage
			A 3.025 Collisions, explosions and impacts
			I 022 Explosions/bombs/blasting/ collision/impacts/ vibration
			J 6.07 Nuclear war
Underground explosions	Construction work included in scenario selection. Nuclear tests considered unlikely.		A 1.32, J 5.38 Explosions
			A 2.56 Sabotage
			I 022 Explosions/bombs/blasting/ collision/impacts/ vibration
			J 5.30 Underground test of nuclear devices
			W 2.028 Nuclear explosions
			W 3.019 Explosions for resource recovery
			W 3.020 Underground nuclear device testing
Administrative (records, markers, planning, control)	Included in scenario selection.		I 189 Loss of markers (misinterpretation)
			I 190, J 7.09, W 3.057 Loss of records
			I 223 Political (loss of institutional control)
			K 11.10 Repository records, markers
			K 11.11 Planning restrictions
Earthmoving/surface disruptions	Irrelevant for deep repository.		A 2.20 Earthmoving
			A 3.115 Water management projects
			I 099 Earth moving projects (civil)
			J 5.27 Human induced actions on groundwater recharge
			J 7.07 Human induced changes in surface hydrology
			K 11.06 Water management schemes
			K 8.37 Earthworks (human actions, dredging, etc)
			W 3.041 Surface disruptions

Factor	Handling in SR-Can	Notes	NEA FEPs/Interactions
Pollution	Included in scenario selection.	Conside-red also in biosphere analyses.	J 7.08 Altered surface water chemistry by humans K 11.07 Groundwater pollution K 11.08 Surface pollution (soils, rivers) W 3.046 Altered soil or water surface chemistry by human activities
Urbanisation	Underground exca-vations caused by urbanisation included in scenario selection.		A 3.112 Urbanization on the discharge site I 227 Urbanization (demographics) J 5.27 Human induced actions on groundwater recharge J 5.28 Underground dwellings J 7.07 Human induced changes in surface hydro-logy J 7.11 City on the site W 3.015 Tunneling W 3.016 Construction of underground facilities (for example storage, disposal, accomodation) W 3.056 Demographic change and urban develop-ment
Archaeological investigations	Included in scenario selection.		I 008b Archaeology (a find during post-closure period) J 5.37 Archeological intrusion W 3.006 Archeological investigations W 3.017 Archeological excavations
Effects of drilling, mining, explo-sions	Included in scenario selection.		W 2.084 Cuttings W 2.085 Cavings W 2.086 Spallings W 3.021 Drilling fluid flow W 3.022 Drilling fluid loss W 3.023 Blowouts W 3.024 Drilling-induced geochemical changes W 3.030 Fluid injection-induced geochemical changes W 3.037 Changes in groundwater flow due to mining W 3.038 Changes in geochemistry due to mining W 3.039 Changes in groundwater flow due to explosions

Table 7. Others. Results of FEP analysis.

Factor	Handling in SR-Can	Notes	
Meteorite impact	Not considered since direct effect of impact much more severe than effects of damage on repository		A 2.43, H 5.2.1, I 197 Meteorite impact A 3.025 Collisions, explosions and impacts J 5.29 Meteorite K 9.11 Extraterrestrial events W 1.040 Impact of a large meteorite