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SR 97 – Identification and structuring of process

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Abstract

This report documents work conducted in recent years to identify processes and interactions of importance to the evaluation of long-term safety of a KBS 3 type deep repository for spent nuclear fuel.

Previous, partly undocumented work regarding interaction matrices is described as well as the THMC diagrams that have been used in the safety assessment SR 97. The coupling between the two sources of information is documented in a database. In the same database, the interaction matrices are briefly documented, while the processes in the THMC diagrams are more thoroughly documented in a special so called Process Report, which forms an important supporting document for SR 97.

Sammanfattning

I denna rapport sammanfattas de senaste årens arbete med att identifiera de processer och interaktioner som behöver beaktas vid utvärderingen av den långsiktiga säkerheten hos ett djupförvar för använt kärnbränsle enligt KBS 3 metoden.

Tidigare delvis odokumenterat arbete med interaktionsmatriser beskrivs liksom de THMC-diagram som använts i säkerhetsanalysen SR 97. Kopplingen mellan de olika informationskällorna dokumenteras i en databas. I samma databas dokumenteras kortfattat interaktionsmatriserna medan processerna i THMC-diagrammen dokumenteras mer utförligt i en särskild s k Processrapport som utgör ett viktigt underlag för SR 97.

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1 Introduction

1.1 Background

Safety assessments of radioactive waste repositories are based on predictive modelling of the performance of the engineered and natural barriers for very long time scales. To evaluate the performance of a repository, assumptions must be made on the future evolution of engineered barriers and natural conditions considering all relevant Features, Events and Processes, FEPs. There is therefore a need for systematic methods to make sure that all alternative future evolutions of the repository system relevant to a reliable assessment are considered.

Different systematic scenario development methods have been applied in safety assessment studies or are presently tested by organisations in Sweden and other countries. A summary of the different methodologies studied by SKB in the period 1981-1994 is given in (Eng *et al*., 1994). During the SR 95 study (SKB, 1995) the Rock Engineering System (RES) approach was applied on a repository for spent nuclear fuel in crystalline rock according to the KBS-3 concept. The basic device in the RES approach, the interaction matrix, was used as a tool for structuring and ranking of FEPs in the repository system. In parallel with the work with the far-field matrix a procedure for construction and documentation of interaction matrices was developed (Skagius *et al*., 1995). This procedure has now been applied to revise and document the buffer and near-field matrices.

In the SR 97 study (SKB, 1999a) the information compiled in the database to the interaction matrices is used as a base for the construction of THMC diagrams. All important Thermal, Hydraulic, Mechanical, and Chemical and radiation related processes, are structured into four THMC-diagrams describing the fuel, canister, buffer/backfill and geosphere respectively. In addition, extensive descriptions of all processes in the THMC diagrams are compiled in a Process Report (SKB, 1999b) to support the analyses and description of the studied system within SR 97.

1.2 Aim and structure of the report

The aim of this report is to present the work that has been performed to structure and identify processes to be considered in evaluating the function and long-term safety of a deep repository for spent fuel according to the KBS 3 concept.

Firstly, a short description of the repository design is given in Chapter 2. In Chapter 3 the construction and documentation of the buffer, near-field and far-field matrices are described. In Chapter 4 an overview is given of the structuring of processes in THMC-diagrams and the content of the Process Report. The coupling of identified processes in the interaction matrices to processes described in the Process Report and vice versa is given in Chapter 5. Finally, concluding remarks are given in Chapter 6.

More detailed information on documentation in matrices and coupling to the Process Report is given in Appendices A-E. In addition, a CD version with all compiled information is available.

2 Repository design

The Swedish deep repository for long-lived waste is planned to be situated at a depth of about 500 m in the crystalline rock. An overview of the repository layout and the engineered barrier design according to the KBS 3 concept is shown in Figures 2-1 and 2-2. A detailed description of the repository design and the conditions at the three hypothetical sites considered within the SR 97 study is given in the report SR 97 – Waste, repository design and sites (SKB, 1999c).

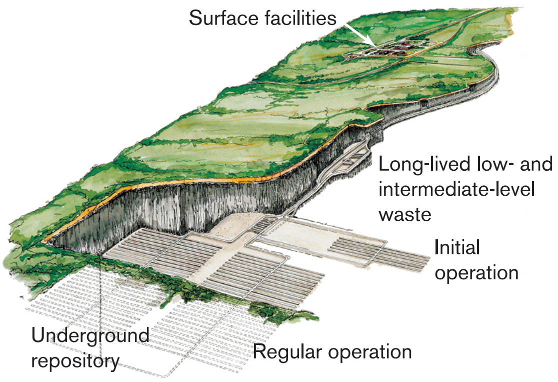

Figure 2-1 The Swedish deep underground repository for long-lived radioactive waste.

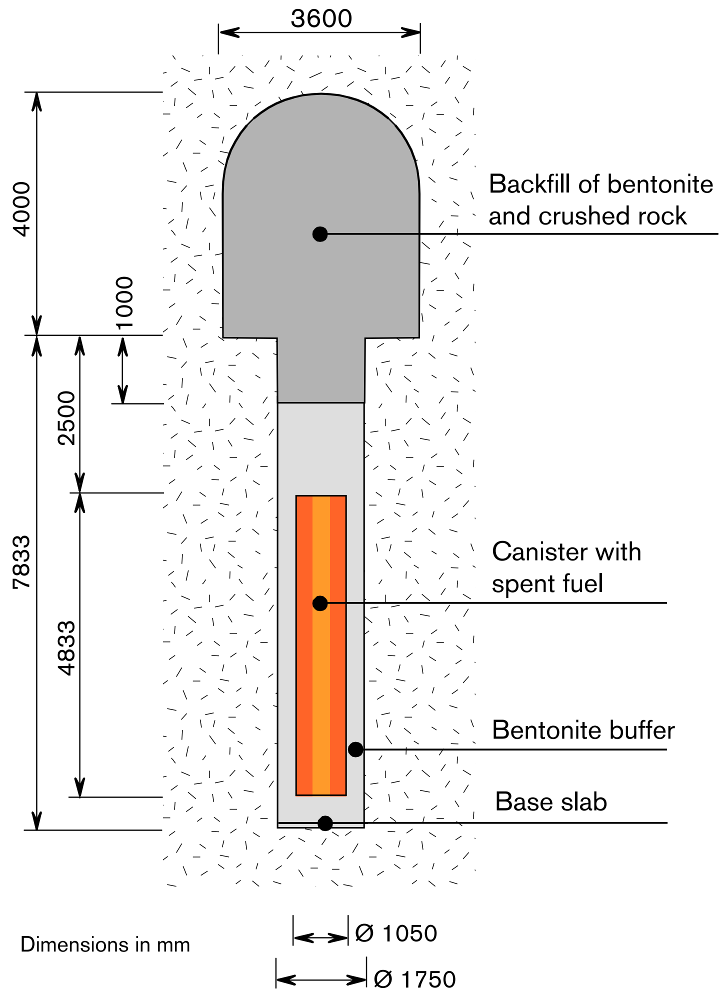

Figure 2-2 Schematic view of deposition hole with canister, buffer materials and backfill in the KBS-3 concept. (Measures in mm)

3 Interaction matrices

3.1 General

The main difference between different systematic scenario development methods concerns the means of structuring the studied system. In the Rock Engineering Systems (RES) approach (Eng *et al.*, 1994), which was developed for approaching rock engineering problems, the structuring of the system is achieved by the use of an interaction matrix. The main variables or parameters of the studied system are identified and listed along the leading diagonal of a square matrix. The interactions between the diagonal elements are given in the off-diagonal terms. This is illustrated in Figure 3-1 together with the clockwise convention for the influence direction. A more detailed description of the RES approach is given in (Hudson, 1992)

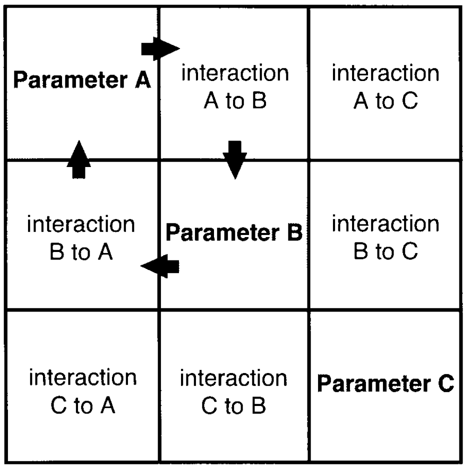

Figure 3-1 Principle of the interaction matrix.

3.2 Construction of interaction matrices

The work with the construction and documentation of the interaction matrix for the far-field of a deep repository for spent fuel (Skagius *et al.*, 1995) has resulted in a procedure for the development of a structured and ranked system. This procedure is schematically shown in Figure 3-2.

Once the purpose of the assessment has been defined, the development of the system is initiated by defining the part of the repository system to be considered. This involves a specification of the repository components to be included, the spatial extension of the system and a description of how it interacts with the surroundings.

The structuring of the system being analysed is obtained by building an interaction matrix showing the interdependencies between FEPs belonging to the system. The first step is to identify the main features and introduce them into the leading diagonal elements in a square matrix.

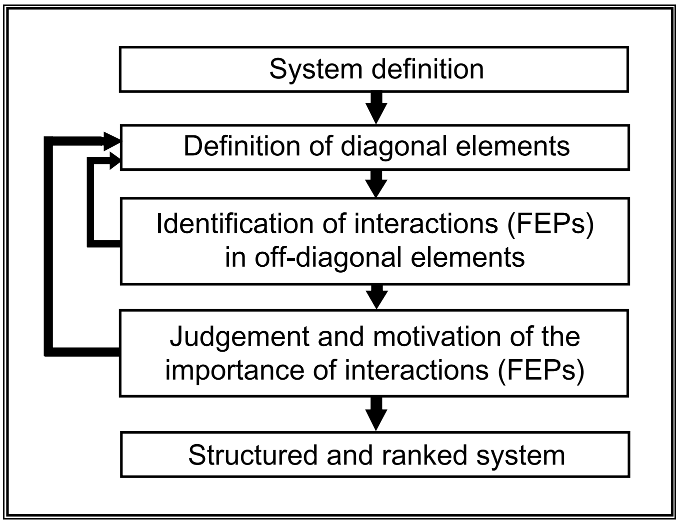

Figure 3-2 Procedure for the development of a structured and ranked system using an interaction matrix.

The system being analysed will be affected by the system outside the boundaries. The impact from the system outside is taken care of by defining boundary conditions. These boundary conditions could be seen as FEPs that would belong to the system being analysed if the spatial extension was increased. For example, if the near-field of a repository is defined to be part of the system being analysed, then the hydrological, geochemical, thermal, and mechanical conditions in the far-field comprise the boundary conditions. To be able to describe relations between the system being analysed and the system on the outside, the boundaries of the system can be part of the leading diagonal elements in the matrix.

When the leading diagonal elements in the matrix are specified and documented, the interactions between the main features in the leading diagonal elements are identified and described by introducing FEPs into the appropriate off-diagonal elements (interaction boxes) in the matrix. This requires a definition of the initial conditions and states of the repository components covered by the system being analysed as well as of the boundary conditions.

The next step is to set priorities to the importance of identified interactions (FEPs) in the interaction matrix. This requires a well-defined priority scale. It should be noted that the priorities set are valid only for the previously defined initial states and boundary conditions. The output from this exercise is a ranked system, in which the most important issues to be focused on in subsequent parts of the performance assessment are highlighted.

Both the identification of interactions and the setting of priorities may reveal requirements on modifications of the definitions of the diagonal elements in the matrix. Building the interaction matrix is therefore an iterative process, as can be seen in Figure 3-2.

Another output from the work with structuring and ranking the system concerns a specification of how the interactions in the matrix could be quantitatively treated in the performance assessment. This is not necessarily a part of the development of a systematic and ranked process system, but it is valuable input to the subsequent parts of the performance assessment.

The structuring of the system being analysed and the ranking of FEPs and interactions require input from various information sources covering a broad range of disciplines. Therefore, this work is preferably done by a group of people with both a general overview of the system and expertise in specific areas.

3.3 Documentation of interaction matrices

In the following sections the organisation of the documentation and the contents of the three interaction matrices, buffer, near-field and far-field for the deep repository for spent fuel, are described. Obviously, it is not possible to compile all the documentation in the graphical description of the matrices. Therefore, the matrices only contain headings and keywords and the full documentation of the matrices is compiled in a database (FileMaker Pro).

In the interaction matrix databases the following topics are documented:

- Purpose of assessment
- Definition of the studied system
- Interaction matrix description, (characteristics covered by individual diagonal elements and descriptions of binary interactions)
- Assigned priorities to interactions with motivations
- Descriptions on how interactions will be treated in a performance assessment, (in some cases).

General information concerning the matrices and the content of the databases is given in Section 3.3.1. More detailed descriptions of the three matrices are given in Sections 3.3.2 to 3.3.4 and in Appendices A-C as well as in the computerised version of the interaction matrix databases.

3.3.1 General information

Purpose of assessment

The purpose of the assessment is to identify the important issues affecting the long-term behaviour of, and the radionuclide migration within the near-field and the far-field rock of an underground repository for spent fuel. The main focus of the more detailed buffer matrix is on the performance of the bentonite buffer surrounding the canisters and on the backfill in the deposition tunnels.

Definition of the system

The basis for the construction of the interaction matrices and the assignment of priorities to the interactions in the matrices is a deep repository for spent nuclear fuel in crystalline rock according to the Swedish KBS-3 system. This means that the spent fuel elements will be encapsulated in copper canisters with inner steel containers and placed in a distributed repository at about 500 m depth in the crystalline bedrock. Bentonite clay will be used as buffer material and a mixture of sand and bentonite as backfill in the deposition tunnels.

The total repository system for spent nuclear fuel is divided into the buffer, the near-field and the far-field subsystems. The near-field consists of the engineered barriers and the nearby rock, and the far-field is represented by the natural/geological barrier. The interaction matrices are developed for a post-closure assessment.

Regarding the definition of the interface between the near-field and the far-field, the following clarification can be made. The rock mass surrounding the repository will be affected, out to a certain distance, by the presence of the repository. This affected zone is here included in both the near-field and the far-field subsystem. The best location for the near-field/far-field interface as well as of the far-field/biosphere interface is a matter of debate and depends on the modelling of radionuclides across these boundaries.

Interaction matrix description

According to the RES-approach, the leading diagonal elements in the matrix should contain the "main physical variables or parameters" of the system. In the construction of the interaction matrices this definition has been extended to "the main features (concepts) or properties governing the system". This was done to be able to include a part of the system with all its characteristics in one diagonal element as well as to be able to include features which cannot directly be expressed as a physical variable or a parameter.

The matrices have been worked through from the top row to the bottom row and by discussing and documenting all the binary interactions between diagonal elements. In the documentation work of the interactions it is often found that the content and description of different diagonal element must be improved. The characteristics of the diagonal elements have thus been defined in an iterative process. The words in the different matrix elements are key words, which should make it possible to associate to the interaction in question. In some cases it may be the reason for the interaction, in other the effect of the interaction. Descriptions of all identified interactions between the diagonal elements are documented in the databases. For each database, about 30% of the off diagonal boxes have been given the priority coding white, implying that no binary interactions between properties in the interacting diagonal-elements have been identified. However, there are also several interaction boxes that contain more than one interaction.

Assignment of priorities to interactions

In working group meetings priorities have been assigned to the interactions described in the interaction matrices. The persons involved in the assignment of priorities and construction of matrices are given in Appendices A – C. The work with the setting of priorities was shown to be a good review and resulted in modifications of diagonal elements and interactions. The definition of the priorities used in the evaluation of the matrices is given in Table 3-1.

Table 3-1 Definition of priorities used in the matrices.

Priority		**Description**
Nr	Colour	
4[a]	Pink[a]	**Important interaction only in the water saturation phase – part of the Performance Assessment.** It can influence other parts of the process system included in this matrix, or other parts of the repository system not included in this matrix.
3	Red	**Important interaction - part of the Performance Assessment.** Could also influence other parts of the process system, (defined in this matrix), or other parts of the repository system. The interaction can be either a prerequisite for the PA or handled by assumptions or modelling efforts in the PA.
2	Yellow	**Interaction present – probably part of the Performance Assessment.** Limited or uncertain influence directly or via this interaction on other parts of the process system, or other parts of the repository system. However, this interaction can be in main focus in other matrices.
1	Green	**Interaction present - do not have to be considered in the Performance Assessment.** Negligible influence on other parts of the process system, (defined in this matrix) and other parts of the repository system.
0	White	**No identified interactions**

[a] *only applicable for the buffer matrix*

A colour coding is used to display the priorities in the interaction matrices. In cases where one interaction box contains more than one interaction, the interaction with the highest priority determines the colour of the interaction box.

In the documentation of the matrices the priority set on each individual interaction can be found together with the motivation for assigning this priority, an identification of the group making the prioritisation and the level of expertise of the group. For the empty interaction boxes, the reasoning behind no identified interactions is given.

Treatment of interactions in performance assessment

In the interaction matrix databases the possible treatment of the interactions, FEPs, in future assessment is indicated only for the far-field matrix. However, in the Process Report (SKB, 1999c) the processes are described and a possible treatment for different scenarios in the SR 97 assessment is suggested.

3.3.2 Buffer matrix

Definition of system

The part of the repository system covered by the matrix contains the fuel, the canister, the engineered barriers and the near-field rock. Reinforcements, in terms of plugs, rock bolts and grouts are also considered. The engineered barriers are the buffer in the deposition holes and the backfill in the tunnels. Shafts and adits are not included. The near-field rock contains deposition tunnels and holes, and its outer boundary is taken to represent the distance from the tunnels and holes to which they influence the structure and behaviour of the surrounding rock. The buffer matrix is developed for post-closure assessment, including the resaturation phase, assuming that radionuclides are not available outside the canister**.**

Interaction matrix description

The buffer matrix consists of 12 diagonal elements and 132 off diagonal elements. A short description of the diagonal elements is given in Table 3-2 and the full description is given in Appendix A. In the buffer matrix about 180 interactions are identified and assigned priorities. About 34% are red, 10% pink, 16% yellow and 40% green. The list of identified interactions with assigned priorities and the persons involved in the construction of the matrix is given in Appendix A. In Figure 3-3 the graphical description of the interaction matrix is shown.

Table 3-2 Diagonal elements in the buffer interaction matrix.

No	Diagonal element	Short description
1.1	Fuel	Spent fuel and metal components of the fuel, such as zircaloy cladding, fuel boxes, spacers, springs, grids etc of stainless steel and inconel in the canister.
2.2	Canister	Copper canister with an inner steel container in which the fuel is located.
3.3	Smectite/buffer	The buffer consists of smectite-rich clay (bentonite) and accessory minerals and impurities.
4.4	Buffer porewater	Water in the buffer that is in contact with the canister, smectite minerals, other clay minerals, non-clay minerals and impurities.
5.5	Non-smectite minerals/impurities	Non-smectite clay minerals, colloids and organics belong to this group.
6.6	Gas	All gaseous phases in the buffer (not inside the canister), backfill and near-field rock, but excluding dissolved gas.
7.7	Temperature	Temperature evolution, temperature gradient, all expressed as functions of time after deposition of canisters in the respective hole. Temperature data for canisters, buffer, backfill and near-field rock.
8.8	Groundwater hydrology	Pressure, flow and properties of water contained in the backfill and nearfield rock.
9.9	Groundwater chemistry	Composition and properties of groundwater in the near-field rock and of the porewater in the backfill in terms of the content and composition of dissolved species, colloids and microbes.
10.10	Near-field rock	Structure, stress conditions, geometry and properties of the rock surrounding the deposition holes and tunnels to a distance influenced by excavation.
11.11	Reinforcements	Construction materials, like concrete, cement and bentonite grouts, cement paste, steel reinforcement, and asphalt.
12.12	Backfill	The backfills considered consist of mixtures of smectitic clay and ballast or pure ballast.

3.3.3 Near-field matrix

Definition of system

This matrix covers the near-field subsystem, i e the fuel, the engineered barriers and the rock mass surrounding the repository. The matrix covers both initially intact canisters and initially defect canisters where the radionuclides in the fuel are accessible to intruding water and available for transport. Repository construction and operation will influence the post-closure conditions in the near-field and is therefore included as a diagonal element in the matrix. The interaction matrix is developed for a post-closure assessment, not including the resaturation phase or the transient temperature phase. The boundary conditions to the near-field are represented by the far-field diagonal elements.

Interaction matrix description

The near-field matrix consists of 15 diagonal elements and 210 off diagonal elements. About 300 interactions have been identified and about 34% were given the priority red, about 4% yellow and about 62% were classified as green. A short description of the diagonal elements is given in Table 3-3 and the full description is given in Appendix B. The total list of identified interactions with priorities and the persons taking part in the construction of the near-field matrix are also given in this appendix. The graphical description of the near-field matrix is shown in Figure 3-4.

Table 3-3 Diagonal elements in the near-field interaction matrix.

No	Diagonal element	Short description
1.1	Fuel	The spent fuel and other metal parts such as zirkaloy cladding, fuel boxes, spacers, grids etc of stainless steel and inconel
2.2	Steel canister	The emplacements of initially damaged steel canisters are included in the definition.
3.3	Copper canister	The copper canister, as well as type and amount of radionuclides associated with solid phases of the canister materials. At repository closure the copper canister can be defect..
4.4	Void	The initial void inside the steel canister and any voids between the inner steel canister and the outer copper canister.
5.5	Buffer	The bentonite buffer in the deposition holes.
6.6	Backfill	The sand/bentonite backfill in the tunnels of the repository.
7.7	Near-field rock	The near-field rock is the rock surrounding the repository which, mechanically, hydrologically and geochemically is affected by the construction and the presence of the repository.
8.8	Construction materials	The construction materials in the repository, such as concrete grout, steel reinforcements and bentonite plugs.
9.9	Near-field water composition	The water composition in the canister interior, in the gap between steel and copper canister, in the engineered barriers and in the near-field rock.
10.10	Near-field water flow	The water flow in the near-field after saturation of the repository.
11.11	Near-field gas	All kind of gases, including radioactive gas, present or generated in the canister, the buffer, the backfill and the near-field rock, but not to dissolved gases.
12.12	Near-field temperature	The temperature in the fuel, the canister, the engineered barriers, as well as in the near-field rock after saturation of the repository
13.13	Near-field rock stress	The rock stresses in the near-field rock around the deposition holes and tunnels
14.14	Radionuclides in near-field water	The radionuclides in the water in the canister, the buffer, the tunnel backfill and the near-field rock. It includes dissolved radionuclides, colloidal/particulate fractions of radionuclides in the water and dissolved radioactive gases
15.15	Far-field	The boundary conditions to the near-field. The element represents the far-field in terms of the rock itself, far-field temperature, gas in the rock, groundwater hydrology, and chemistry of the groundwater as well as radionuclides in the water.

3.3.4 Far-field matrix

Definition of system

In the far-field matrix some events regarded as a part of the normal evolution of the conditions outside the system are considered. For example, the biosphere element includes future climate changes. The ambition is to have the same set of diagonal elements for the far-field whatever scenario being analysed. The boundary conditions to the far-field are represented by the diagonal elements 2.2 Buffer/backfill/source and 13.13 Biosphere. Repository construction and operation will influence the post-closure conditions in the far-field and is therefore included as a diagonal element in the matrix.

Interaction matrix description

The far-field matrix comprises 13 diagonal elements and 156 off diagonal elements, and is shown in Figure 3-5. An overview of defined diagonal elements is given in Table 3-4 and the full descriptions are given in Appendix C. In total about 150 interactions are identified and assigned priorities. About 40% of the identified interactions are classified as red and yellow, respectively and about 20% are green. In Appendix C persons involved in the work with the matrix and the total list of interactions with assigned priorities are given.

Table 3-4 Diagonal elements in the far-field interaction matrix.

No	Diagonal element	Short description
1.1	Construction/layout	This element is introduced to take care of the influence of the construction work, the operation of the deep repository and the layout of the repository on the definition of the initial conditions of the repository system
2.2	Buffer/backfill/source	The properties of the backfill material in the tunnels of the repository and the source term for the radionuclide transport . This element covers also the gas generated within the buffer. In addition, the heat generated by the waste and the temperature within the buffer and the backfill are included in the definition. This element constitute boundary conditions for the far-field.
3.3	EDZ	The Excavation Damaged Zone is defined as the zone extending around an underground opening which, is affected by the excavation process and subsequent mechanical processes.
4.4	Rock matrix/ mineralogy	This element represents the intact rock and includes mineralogy as well as thermal and mechanical properties.
5.5	Natural fracture system	The natural fracture system includes fracture mineralogy as well as thermal and mechanical properties of the natural fractures.
6.6	Groundwater chemistry	The groundwater chemistry in the EDZ and in the far-field rock
7.7	Groundwater movement	The fluid flow in the far-field rock, the groundwater movement in the tunnels, in the EDZ, and the mixing of different waters.
8.8	Groundwater pressure	The groundwater pressure here defined as the hydraulic head. In addition to hydraulic head this element also refers to the absolute pressure.
9.9	Temperature/heat	This element includes the temperature in the far-field as well as in the EDZ around tunnels and deposition holes
10.10	Rock stresses	Rock stresses which can be measured in-situ. The stresses in the far-field rock and in the EDZ around the tunnels and the deposition holes are included.
11.11	Gas generation and transport	Gas generation and gas transport in the rock matrix, in the natural fracture system, in the EDZ and in the backfilled tunnels. Gas includes not dissolved gases but gas pressure is also included.
12.12	Transport of radionuclides	The transport of radionuclides in the far-field rock, in the EDZ around tunnels and deposition holes, and in the backfilled tunnels.
13.13	Biosphere	All processes in the biosphere including vegetation, climate, wells, topography etc. This element constitutes boundary condition for the far-field

Buffer

FUEL	1.2 Radiation	1.3 Radiation	1.4 Radiolysis	1.5 Radiation	1.6 Radiation	1.7 Radioactive decay	1.8	1.9 Radiation/ radiolysis	1.10 Radiation	1.11 Radiation	1.12 Radiation
2.1 Confine-ment	CANISTER	2.3 Pressurizing Expansion	2.4 Ion release	2.5	2.6 Corrosion	2.7 Heat transport	2.8 Flow paths	2.9	2.10	2.11	2.12
3.1	3.2 Canister movement Mech. impact Shearing	SMECTITE/ BUFFER	3.4 Diffusivity Phys. state Diss./prec. Ion exchange Colloid form. Sorption Flow in buffer Suction	3.5 Movement of species	3.6 Gas incl., rel. and transp.	3.7 Heat transp. Buffer temp.	3.8 Flow in nearfield rock	3.9	3.10 Swelling pressure Self-sealing	3.11 Reinforce-ments Buffer exp.	3.12 Buffer swelling
4.1	4.2 Corrosion Pressurizing canister	4.3 Buffer swelling Smectite diss. Prec. of sec. minerals Ion-exch./sorp. Conv. of smectite Microstruc.	BUFFER PORE-WATER	4.5 Dissolution Precipitation	4.6 Vapor press. Diss. of gas Gas in buffer Gas comp./exp. Microbial act.	4.7 Heat conductivity Heat of wetting	4.8 NF hydrology	4.9 Transp. of species	4.10 Mechanical impact on rock	4.11	4.12 Hydr. impact on backfill
5.1	5.2 Corroding contacting canister	5.3 Degrading contacting smectite	5.4 Dissolution Precipitation Formation of colloids	NON-SMECTITE MINERALS/ IMPURITIES	5.6	5.7 Heat conductivity	5.8	5.9	5.10	5.11	5.12
6.1	6.2 Mech. impact on canister Corrosion	6.3 Piping Erosion Buffer dehyd.	6.4 Dissolution Pressurizing	6.5 Chemical reactions	GAS	6.7 Heat transport	6.8 Gas in NF rock	6.9 Dissolution	6.10 Saturation Gas-rock interact.	6.11 Pressurizing	6.12 Backfill sat. Piping
7.1 Fuel alteration	7.2 Therm. exp./contr. Struct. alt. Press. change	7.3 Microstruct. Therm. prop. Swelling Exp./contr. Shear strength Chem. equil. Kinetics	7.4 Vapor./cond. Porewater rheology Kinetics Chem. equil. Therm. induced transp. and press.	7.5 Chem. equil. Kinetics	7.6 Gas compr./exp. Vapor transp. Dissolution	TEMPERA-TURE	7.8 Boyancy eff. Heat-aff. flow	7.9 Chem. equil. Kinetics	7.10 Therm. exp./contr. Shearing Kinetics Chem. equil.	7.11 Therm. exp./contr. Degr. of rein-forcements	7.12 Chem. equil. Kinetics Hydr. cond.
8.1	8.2	8.3 Erosion Water sat. and press.	8.4 Flow in buffer	8.5 Erosion of buffer	8.6 Gas compr./exp. Two-phase flow	8.7 Heat transport through convection	GROUND-WATER HYDRO-LOGY	8.9 Saturation Groundwater composition	8.10 Erosion Particle transport	8.11 Erosion Load on reinforce-ments	8.12 Erosion Saturation
9.1	9.2	9.3	9.4 Exch. of species	9.5	9.6 Dissolution	9.7 Heat transport	9.8 Density grad. Viscosity changes	GROUND-WATER CHEMISTRY	9.10 Dissolution/ precipitation	9.11 Degr. of rein-forcements Cement mat.	9.12 Diss./prec. Ion-exch./sorp.
10.1	10.2	10.3 Confinement Rock displac. Buffer exp. and dim. Rock creep	10.4 Earth currents	10.5	10.6 Gas transp. and inclu.	10.7 Heat transport	10.8 Hydrology	10.9 Diss./prec. Earth currents Colloid transp. Sorption Matrix diff.	NEARFIELD ROCK	10.11 Mech. impact	10.12 Confinement Backfill exp.
11.1	11.2 Being lost in deposi-tion holes	11.3 Confine-ment	11.4	11.5	11.6 Corr. Storing of gas	11.7 Heat transport	11.8 NF hydrology	11.9 Degr. of reinforce-ments	11.10 Mech. support	REINFORCE-MENTS	11.12 Confine-ment
12.1	12.2	12.3 Confine-ment	12.4	12.5	12.6 Gas escape and inclusion	12.7 Heat flow	12.8 NF hydrology	12.9 Diss./prec. Ion-exch./sorp.	12.10 Mech. impact and support Backfill expand.	12.11 Mech. impact	BACKFILL

Figure 3-3 Graphical presentation of the buffer interaction matrix.

Nearfield

FUEL	1.2 Radiation Neutron activation	1.3 Radiation Neutron activation	1.4 Dissolution/ precipitation Cladding corrosion	1.5 Radiation	1.6 Radiation	1.7 Radiation	1.8 Radiation	1.9 Radiolysis Fuel oxidation Diss./prec., colloid form Cladding corr.	1.10	1.11 Helium production Radiolysis Cladding corrosion Radioactive gas	1.12 Heat generation	1.13	1.14 Diss./prec. Instant release Cladding corr.	1.15
2.1 Confine-ment	STEEL CANISTER	2.3 Yawning	2.4 Corrosion products Void size	2.5	2.6	2.7	2.8	2.9 Corrosion	2.10 Integrity	2.11 Corrosion gas Gas release	2.12 Heat transport	2.13	2.14 Sorp./desorp. Diffusion Colloid filter Dissolution	2.15
3.1	3.2 Confine-ment Galv. corr.	COPPER CANISTER	3.4 Void size	3.5 Mech. load Exp./compr.	3.6	3.7	3.8	3.9 Corrosion	3.10 Integrity Intersects flowpaths	3.11 Gas release	3.12 Heat transport	3.13	3.14 Sorp./desorp. Diffusion Colloid transp. Dissolution	3.15
4.1 Fuel alt. Diss./prec. Cladding corr. Solubility	4.2 Corrosion Solubility	4.3 Canister creep	VOIDS IN CANISTER	4.5 Swelling	4.6	4.7	4.8	4.9 Solubility Extent of reactions	4.10 Internal water pressure	4.11 Gas expansion/ compres-sion	4.12 Heat transport	4.13	4.14 Diss./prec./ vapor. Sorp./desorp. Inst. release of RN	4.15
5.1	5.2	5.3 Canister movement Mech. impact Shear Stress corr. cracking	5.4 Buffer intrusion	BUFFER	5.6 Swelling	5.7 Intrusion	5.8 Mechanical impact	5.9 Colloid gener. Diss./prec. Ion-exch./sorp. Diffusion Colloid transp. Phys. state of water	5.10 Intersects flow paths Flow in buffer Water exch., canister	5.11 Gas flow in buffer	5.12 Heat transport	5.13 Swelling Mech. impact on rock	5.14 Ion-exch., sorp./desorp. Diff. Colloid filter Diss./prec./ vapor.	5.15
6.1	6.2	6.3	6.4	6.5 Confine-ment	BACKFILL	6.7 Intrusion	6.8 Mechanical impact	6.9 Colloid gener. Diss./prec. Ion-exch./sorp. Diffusion Colloid transp.	6.10 Local hydrology	6.11 Gas flow	6.12 Heat transport	6.13 Swelling Tunnel dim.	6.14 Ion-exch./ sorp./desorp. Diffusion Colloid transp. Dissolution	6.15
7.1	7.2	7.3	7.4	7.5 Rock displac. Confinement Buffer exp.	7.6 Rock movements Confinement Backfill exp.	NEAR-FIELD ROCK	7.8 Reinforce-ments	7.9 Sorption Matrix diff. Diss./prec., colloid gener. Earth currents Molecular diff.	7.10 Local hydrology	7.11 Gas flow	7.12 Heat transport	7.13 Stress relaxation	7.14 Sorp./desorp. Matrix diff. Molecular diff. Dissolution	7.15
8.1	8.2	8.3 Mechanical impact	8.4	8.5 Confine-ment	8.6 Confine-ment	8.7 Mechanical support	CONSTRU-CTION MATERIALS	8.9 Alteration Stray materials	8.10 Flow pattern	8.11 Corrosion Gas flow	8.12 Heat transport	8.13	8.14 Sorp./desorp. Diffusion Dissolution	8.15
9.1 Fuel alter., diss./prec. Cladding corr.	9.2 Corrosion	9.3 Corrosion	9.4	9.5 Ion-exch. Diss./prec. Swelling Illitization	9.6 Ion exch./sorp. Diss./prec. Swelling	9.7 Fracture alteration Rock alteration	9.8 Alt. of construct. material Cement matur.	NEAR-FIELD WATER COMPOSI-TION	9.10 Density, viscosity	9.11 Diss. of gas Microb. activity Gas gener.	9.12 Heat transport	9.13	9.14 RN diss./prec., sorp./desorp. Colloid transp. Diss. of radioactive gas	9.15 Exchange
10.1	10.2	10.3	10.4 Water transport	10.5 Pressure Erosion	10.6 Erosion Solubility	10.7 Erosion of rock Diss./prec.	10.8 Erosion Solubility Grouting	10.9 Transport of species Solubility	NEAR-FIELD WATER FLOW	10.11 Gas compr./exp., dissolution Two-phase flow	10.12 Heat convection	10.13 Effective stress	10.14 Transport of dissolved RN and gas Diss./prec./vapor.	10.15 Hydraulic gradient
11.1 Cladding corrosion H2 catalysis	11.2 Corrosion Mech. impact	11.3 Corrosion Internal impact	11.4	11.5 Piping Flotation Porewater press. Dehydration Chem. reactions	11.6 Dehydration Piping	11.7 Dehydration Chemical reactions Fractures	11.8 Mechanical impact	11.9 Gas dissolution Radiolysis	11.10 Displace-ment Two-phase flow	NEAR-FIELD GAS	11.12 Heat transport	11.13	11.14 Colloids on gas bubbles Dissolution of radioactive gas	11.15 Gas flow Rel. of gas
12.1 Struc./chem. alt. Kinetics Equilibria Volatility Therm. exp./contr.	12.2 Exp./contr. Struct. alt. Kinetics Equlibria	12.3 Exp./contr. Struct. alt. Kinetics Equlibria	12.4 Phase changes	12.5 Kinetics Chem. equil. Hydr. cond. Swelling Therm. exp./contr. Porewater press. Therm. prop. Shear	12.6 Kinetics Equilibria Hydraulic conductivity	12.7 Fracturing Fracture aperture Kinetics Equlibria Thermal conductivity	12.8 Expansion/ contraction Kinetics Equilibria	12.9 Kinetics Equilibria Phase ch. Diffusion Therm. grad. transp.	12.10 Convection cells Viscosity	12.11 Expansion/ compression Gas dissolution	NEAR-FIELD TEMPERA-TURE	12.13	12.14 Kinetics Equilibria Diffusion	12.15 Heat transfer
13.1	13.2	13.3	13.4	13.5 Rock displac. and creep	13.6 Rock displac. and creep	13.7 Fracturing Fracture aperture	13.8 Deforma-tions	13.9	13.10	13.11	13.12	NEAR-FIELD ROCK STRESSES	13.14	13.15 Stress
14.1 Dissolution/ precipitation	14.2 Sorption, coprec.	14.3 Sorption, coprec.	14.4	14.5 Sorp., prec. Radiation eff.	14.6 Sorp., prec. Radiation eff.	14.7 Sorp., prec. Radiation eff.	14.8 Sorp., prec. Radiation eff.	14.9 Contamination Redox front Radiolysis	14.10	14.11 Dissolution/ evaporation	14.12 Heat generation	14.13	RADIO-NUCLIDES IN NEAR-FIELD WATER	14.15 RN release
15.1	15.2	15.3	15.4	15.5	15.6	15.7	15.8	15.9 Earth currents Exchange	15.10 Regional flow	15.11 Gas flow and exch.	15.12 Heat exchange	15.13 Stress	15.14 Exchange	FAR-FIELD

Figure 3-4 Graphical presentation of the near-field interaction matrix.

Farfield

CONSTRUCTION/ LAYOUT	1.2 Excavation method	1.3 Excavation method Grouting Reinforcement	1.4	1.5 Displacement effects	1.6 Construction materials Stray materials	1.7	1.8 Resaturation	1.9 Repository depth Ventilation	1.10 Tunnel dimension	1.11 Ventilation Gas gener. Alt. of reinf.	1.12	1.13 Environmental impact
2.1 Swelling Temperature	BUFFER/ BACKFILL/ SOURCE	2.3 Swelling	2.4	2.5 Swelling	2.6 Colloid source Groundwater composition	2.7 Changed flow, holes and tunnels	2.8 Resaturation	2.9 Heat transport	2.10 Swelling pressure	2.11 Gas transport	2.12 RN transport	2.13
3.1 Excavation method Amount of reinforcement	3.2 Bentonite swelling Rock fallout	EDZ	3.4	3.5	3.6 Diss./prec. Colloid and particulate generation	3.7 Changed permeability	3.8	3.9 Heat transport	3.10 Fractures affected	3.11 Air diff. Gas transp.	3.12 Matrix diff. Sorption	3.13
4.1 Layout/ construction method	4.2	4.3 Magnitude and geometrical extent	ROCK MATRIX/ MINERALOGY	4.5 Fracture characteristics and infilling mineralisation	4.6 Rock-water interaction	4.7 Matrix K Rock compressibility	4.8	4.9 Heat transport	4.10 Genesis, tectonic history and rock type	4.11 Radon generation	4.12 Sorption Matrix diffusion	4.13 Land-use Potential human intrusion
5.1 Avoid major fracture zones Constructability	5.2	5.3 Mechanical properties and fracture frequency	5.4	NATURAL FRACTURE SYSTEM	5.6 Diss./prec. Colloid generation	5.7 Flow paths Connectivity Channeling Storage capa.	5.8	5.9 Heat transport	5.10 Stress magnitude and orientation	5.11 Transport path for gas	5.12 Molecular diff. Matrix diff. Sorption	5.13 Wells
6.1 Depth affected by redox pot. Construction materials	6.2 Chem. alt. Water chem.	6.3 Precipitation/ bacterial growth	6.4 Groundwater rock interaction	6.5 Prec. and diss. of fracture minerals	GROUNDWATER CHEMISTRY	6.7 Density Viscosity	6.8 Density affects groundwater head	6.9 Heat transport	6.10	6.11 Gas gener. Microb. act.	6.12 Sorp. Prec./diss. Colloid transport	6.13 Water-use Biotopes
7.1 Canister positioning Construction methods	7.2 Saturation Bentonite erosion	7.3 Erosion	7.4	7.5 Erosion and sedimentation	7.6 Mixing	GROUNDWATER MOVEMENT	7.8 Equalisation of pressures	7.9 Forced heat convection	7.10	7.11 Two-phase flow	7.12 Transport of diss. gas and RN Dispersion	7.13 Recharge and discharge
8.1 Construction methods	8.2	8.3	8.4	8.5	8.6 Solubility	8.7 Driving force due to pressure gradient	GROUNDWATER PRESSURE	8.9	8.10 Effective stress	8.11 Gas solubility and exp./comp.	8.12	8.13 Potential effect on vegetation
9.1	9.2 Temperature in buffer/ backfill	9.3	9.4 Thermal expansion and conductivity	9.5 Permafrost	9.6 Solubility, kinetics	9.7 Heat convection	9.8 Buoyancy eff.	TEMPERATURE/HEAT	9.10 Thermal expansion	9.11 Gas solubility and exp./comp.	9.12 Molecular diff. Matrix diff. Sorption	9.13
10.1 Design/layout Construction methods	10.2 Swelling Rock fallout	10.3 Mechanical stability Fracture aperture	10.4 Mechanical stability	10.5 Mechanical stability Fracture aperture	10.6	10.7	10.8 Confined aquifers	10.9	ROCK STRESSES	10.11	10.12	10.13 Mechanical stability
11.1 Ventilation problems	11.2	11.3 Opening of fractures Heat conduction	11.4 Fracturing Thermal properties	11.5 Fracture aperture	11.6 Diss. of gas	11.7 Two-phase flow	11.8 Capillary forces	11.9 Gas law	11.10	GAS GENERATION AND TRANSPORT	11.12 Colloid sorption on gas bubbles	11.13 Rel. of radioactive gas
12.1 RN release	12.2	12.3	12.4	12.5	12.6 Radiolysis Redox front	12.7	12.8	12.9	12.10	12.11	TRANSPORT OF RADIONUCLIDES	12.13 RN release
13.1 Siting Design/ layout	13.2	13.3	13.4	13.5	13.6 Infiltrating water	13.7 Surface water recharge & percolation	13.8 Land use Climatic & tidal driving forces Hydraulic gradient	13.9 Climatic driving forces	13.10 Glaciation Erosion	13.11	13.12	BIOSPHERE

Figure 3-5 Graphical presentation of the far-field interaction matrix.

4 Processes, interactions and diagrams on a THMC format

This chapter consists of slightly changed excerpts from the SR 97 - Main Report, Chapter 4 (SKB 1999a).

4.1 General

A systematic safety assessment requires a description of all known internal processes of any conceivable importance, their interrelationships and the properties of the repository that are influenced by the particular process. The structure of the description should provide both an overview and details. Another requirement on the structure is that it must be able to be used throughout in the presentation of the safety assessment. Previously, interaction matrices have been utilised to describe the system of internal processes. The description has largely been independent of the rest of the assessment and difficult to integrate into the report. Partly for this reason, a new structure for system description has been developed in SR 97.

This structure is based on a graphic representation of the different processes in diagrams. It is based on a division of the system into four parts, namely fuel, canister, buffer/backfill and geosphere, and the processes into thermal, hydraulic, mechanical, chemical and radiation-related processes.

In looking for a structure for the system description, it is noted that the repository system consists of a number of consecutive barriers or subsystems where the internal subsystems are completely surrounded by the external ones. Innermost in the system is the fuel. All fuel is surrounded by canisters, all canisters are surrounded by buffer and backfill material in tunnels and shafts. All buffer and backfill is surrounded by geosphere. Outside the geosphere is what is meant by the “surroundings”, consisting of the biosphere etc. This means that the system can be represented “one-dimensionally” with four subsystems that directly border on and interact with each other, see Figure 4-1.

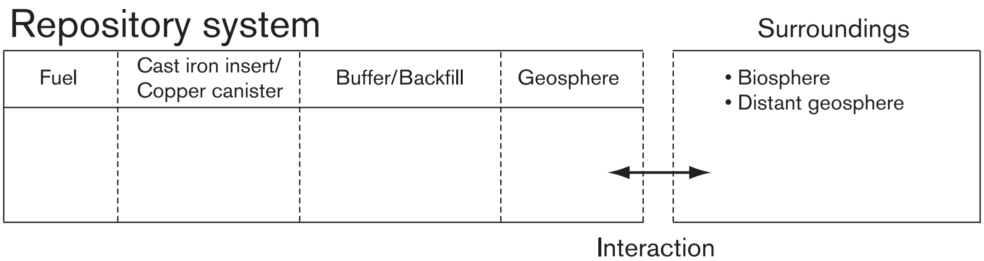

Figure 4-1 Division in repository system (fuel, canister, buffer/backfill and geosphere) and surroundings.

Buffer and backfill have been described as a single subsystem for two reasons: Firstly, they have similar composition and properties, and secondly, a situation is then obtained where buffer and backfill only border outwardly on the geosphere. If buffer and backfill were described as separate parts, the buffer would border on both geosphere and backfill, and the simplicity of the one-dimensional description would be lost.

4.2 Construction of THMC diagrams

All relevant processes can be arranged in the above structure. The set of processes used in SR 97 has been taken from earlier work with interaction matrices, where processes and interactions of importance for the evolution of the repository have been identified, see Chapter 3. Almost all information in the matrices has been arranged in THMC structures of processes and interactions or included in the description of the initial state, see Chapter 5.

To lend further structure to the description, it can be noted that two subsystems, e.g. buffer and rock, mainly influence each other thermally (by heat flow), hydraulically (by above all water flow when the buffer absorbs water from the rock), mechanically (when the buffer swells due to water uptake and then exerts a swelling pressure on the walls of the deposition hole) and chemically (above all by exchange of solutes between groundwater in the rock and pore water in the buffer). The different processes that occur within a subsystem are also primarily thermal, hydraulic, mechanical or chemical by nature. The graphical presentation of processes in THMC-diagrams for the defined subsystems, fuel, canister, buffer/backfill and geosphere is given in Figures 4-3 to 4-6.

The description also permits a clear distinction to be made between processes within a subsystem and the interaction between different subsystems. The interaction or process categories thermal (T), hydraulic (H), mechanical (M) and chemical (C) are often referred to collectively as THMC in the literature. Since the assessment concerns a system where radiation from radioactive materials plays a principal role, radiation-related interactions and processes also enter in, particularly radioactive decay in the fuel and attenuation of the radiation that is emitted from an intact canister. A fifth category, radiation-related processes (R), is therefore added to the THMC processes.

A large portion of the assessment is concerned with radionuclide transport, which is also important for evaluation of the safety of the repository. Radionuclide transport is in fact a collective consequence of a number of hydraulic and chemical processes and is therefore covered by the processes in these categories. Since radionuclide transport comprises such an important part of the safety assessment, the different subprocesses involved in radionuclide transport have been gathered in a special category in each subsystem, see Figures 4-3 to 4-6.

Microbial processes occur in buffer/backfill and in the geosphere. They have been categorised among the chemical processes. Another option would have been to have a special category for biological processes. This has been avoided because there are few biological processes, and because they are of limited importance for the evolution of the system at depth. Biological processes in the biosphere-geosphere interface have though a decisive influence on the composition of the water that penetrates down into the bedrock from the biosphere.

It is not always self-evident which category a process should be assigned to, just as there are no clear-cut limits between different fields in the natural sciences. The categorization is mostly an aid in visualizing lines in the system structure. In doubtful cases, the category considered to be the most expedient for obtaining a clear and distinct system description has been chosen.

4.2.1 Variables

The state in a subsystem is characterised at any given moment by a set of variables (bold in the examples given below). The state of the geosphere is, for example, characterised by its **temperature**, which varies in time and space, by its **fracture geometry** (which varies widely in space, but hardly at all in time), by **groundwater flow**, **groundwater composition**, **rock stresses**, etc.

Together, the variables should characterise the system sufficiently well to enable a safety assessment to be conducted. Some variables, such as temperature and groundwater composition, are used or determined directly in analyses and calculations, while others serve as a basis for deriving important properties of the system: The thermal conductivity and density of the geosphere can, for example, be calculated from the variable **matrix minerals**. The variables should also be independent of each other, in order to provide a clear-cut description of the coupled system of processes.

All variables are influenced by one or more processes, and all processes are influenced by one or more variables. The process heat transport in the geosphere, Figure 4-2, serves as an example: Heat transport takes place principally by heat conduction, and the thermal conductivity of the geosphere is determined by the mineral composition of the rock matrix or by the variable **matrix minerals**, which thus influences heat transport. Heat can also be transported to some extent with the flowing groundwater (heat flow), and the **groundwater flow** therefore influences heat transport. The **temperature** both influences and is influenced by the processes: Heat transport changes the temperature, but the temperature difference between different parts of the geosphere is also the very driving force for the transport process. Finally, the geosphere's geometric boundary with the canister holes must also be included in the description of heat transport, since the heat flow from buffer and backfill to the geosphere is the most important source of heat transport. This is expressed by the variable repository **geometry/boundary**.

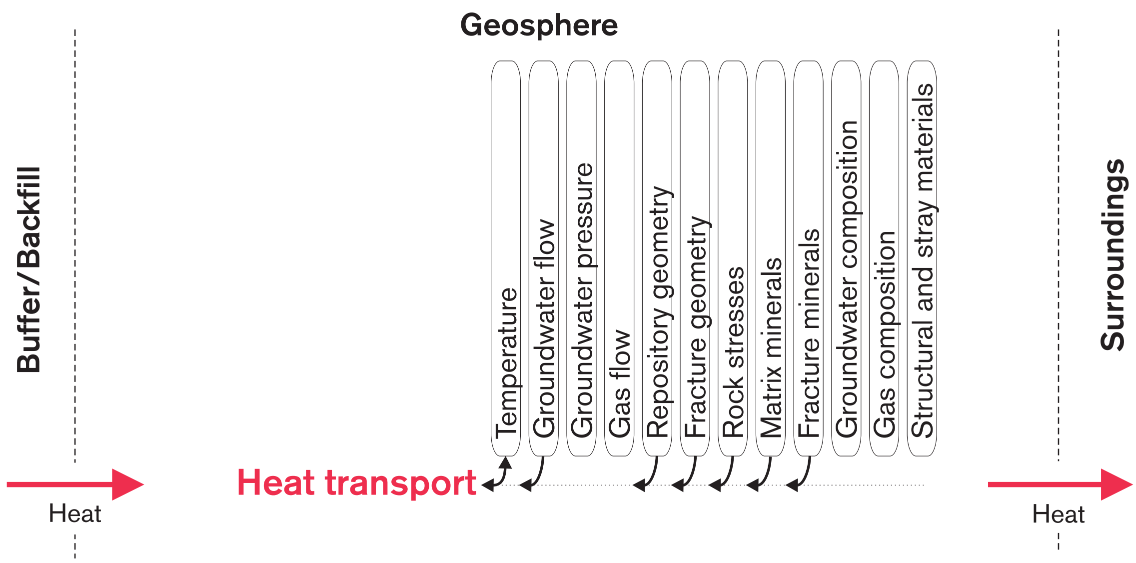

Figure 4-2 Heat transport in the geosphere.

The variables in the THMC diagrams correspond to the diagonal elements in the interaction matrices, but are more strictly defined as measurable quantities, whereas the definitions of the diagonal elements are in general broader. All variables in the THMC diagrams are defined both in the SR 97 - Main Report (SKB 1999a) and in the Process Report (SKB1999b).

4.3 Documentation in the Process Report

The thermal, hydrological, mechanical, chemical and radiation related processes identified as internal processes of importance for the post-closure evolution and safety of a KBS-3 repository for spent nuclear fuel are comprehensively and coherently described and documented in the Process Report, “SR 97 - Processes in repository evolution”, (SKB, 1999b). The report is used as background for the main report for SR 97 and is the first version of a report that will be revised prior to every safety report.

In the Process Report (SKB, 1999b) a general description of the identified processes is given, modelling and experimental studies are documented, and uncertainties in data as well as in understanding of the process is discussed. In addition, suggestions are given on how the processes can be considered for different scenarios in the assessment. The description of processes in the report follows the division and the structure of the THMC-diagrams. The list of contents is given in Appendix D. The graphical presentation of processes in THMC-diagrams for the defined system parts, fuel, canister, buffer/backfill and geosphere is given in Figures 4-3 to 4-6.

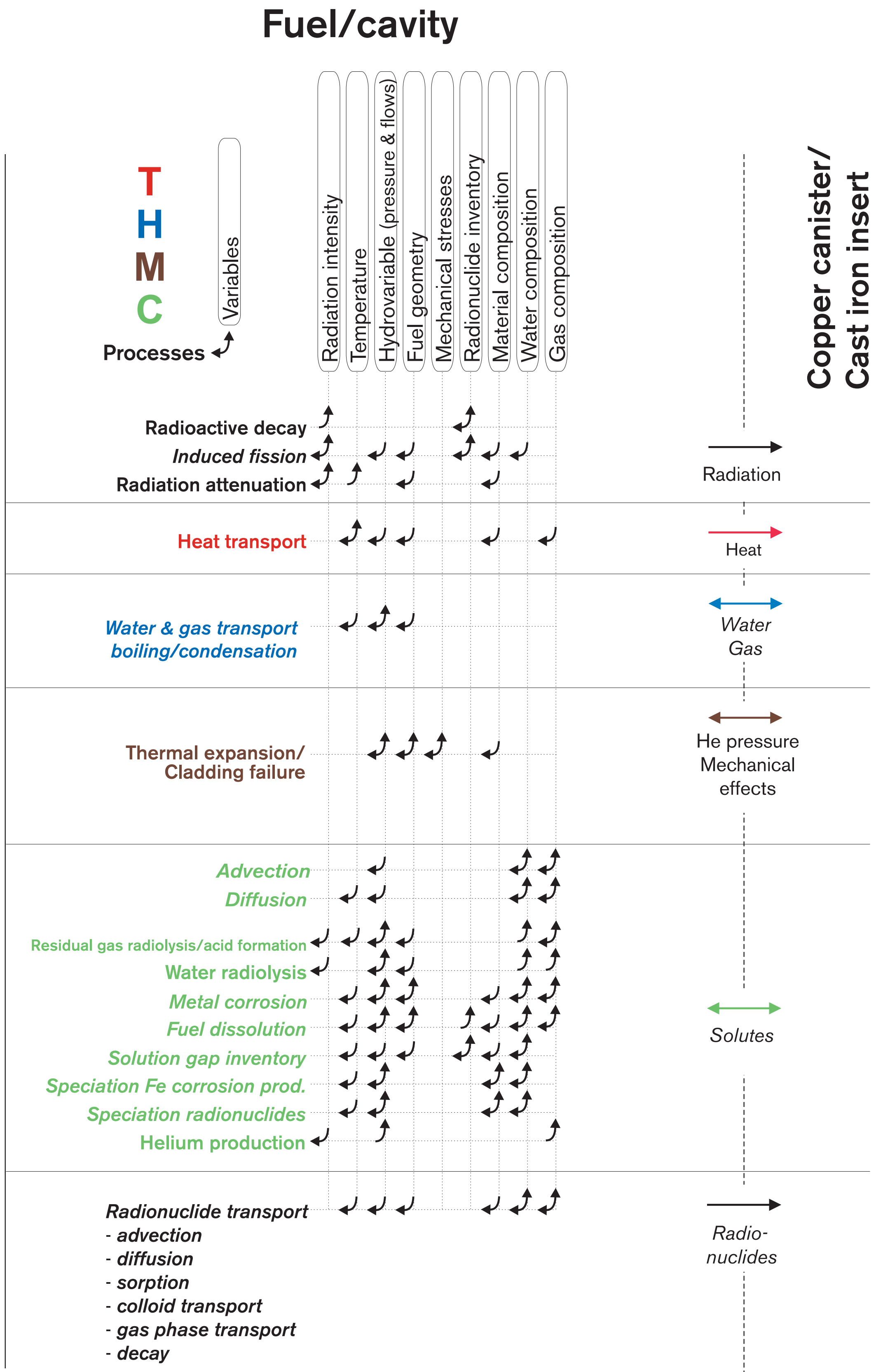

Figure 4-3 THMC-diagram for processes in the fuel and the cavity in the canister.

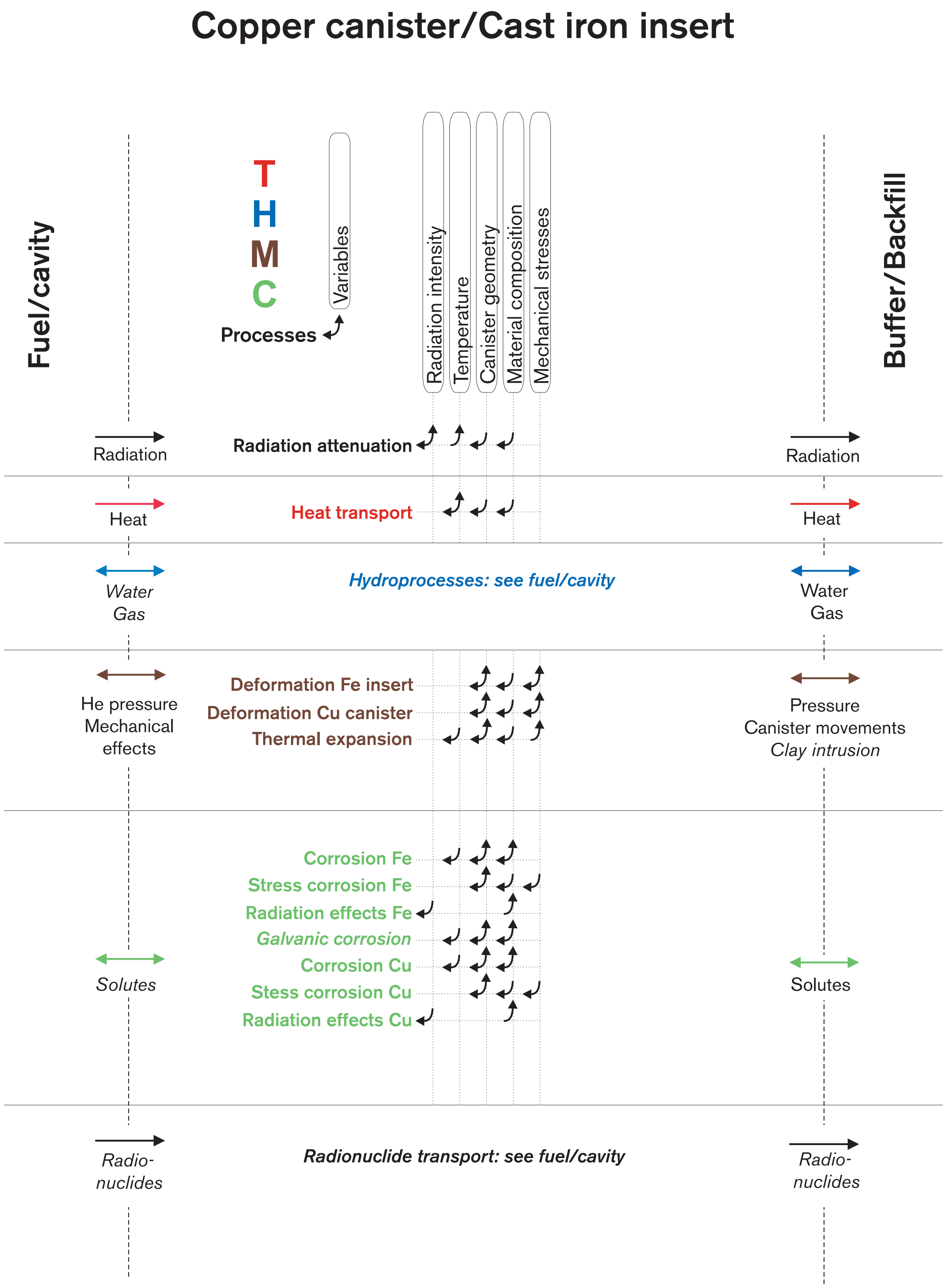

Figure 4-4 THMC-diagram for processes in the cast iron insert and the copper canister.

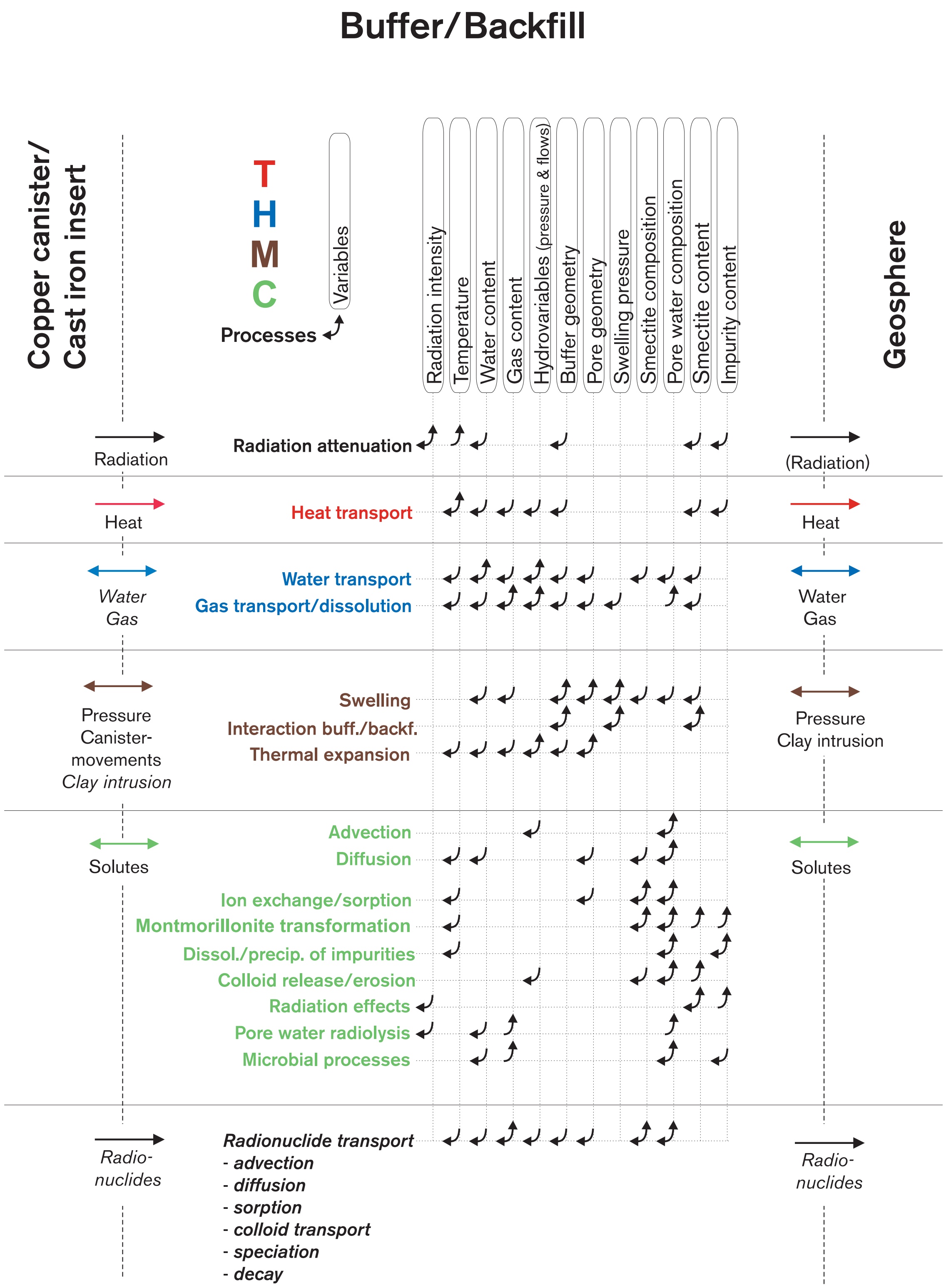

Figure 4-5 THMC-diagram for processes in the buffer and backfill.

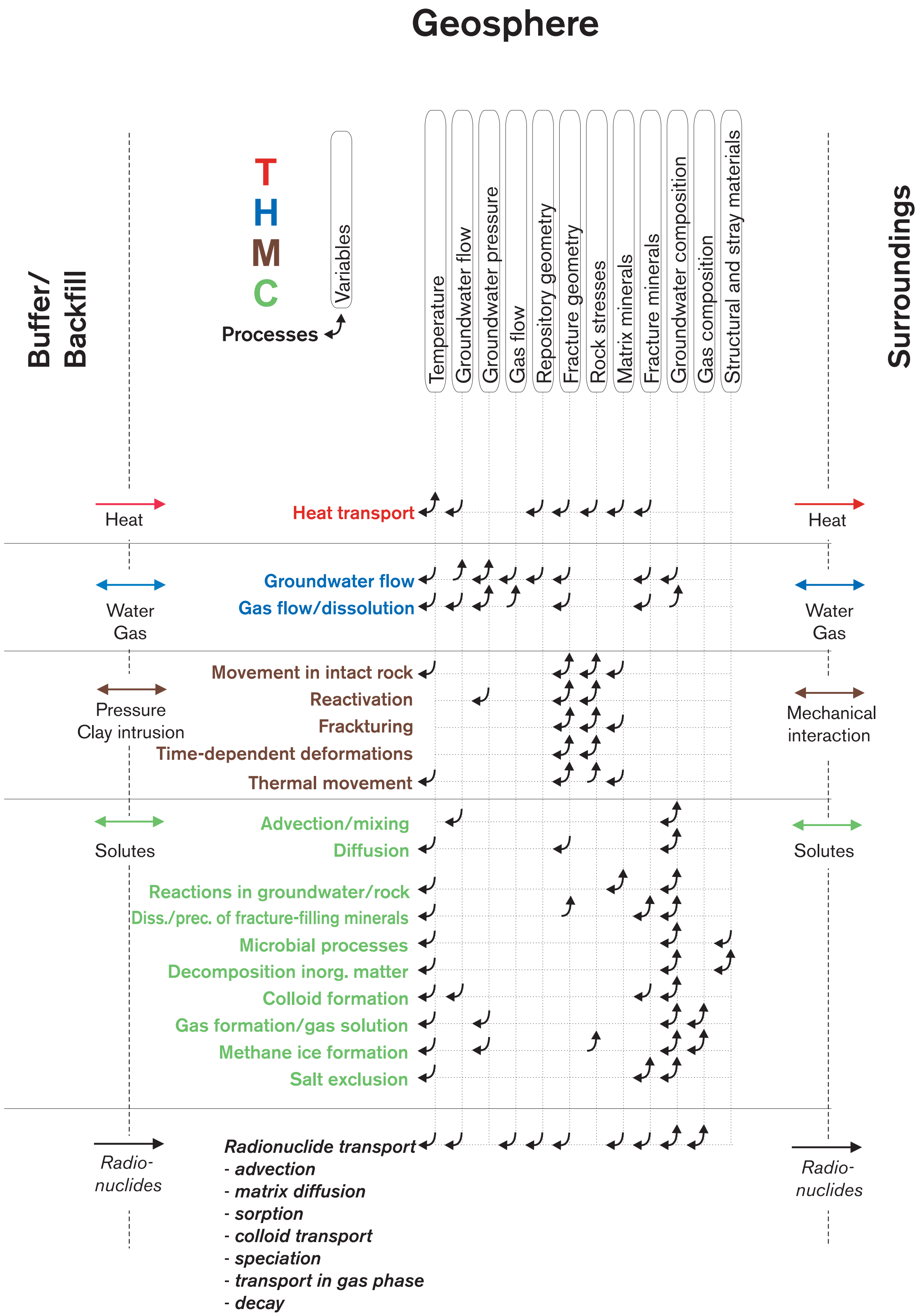

Figure 4-6 THMC-diagram for processes taking place in the geosphere.

5 Transfer of information from Interaction matrices to Process Report/THMC-diagrams

In using the THMC format for the system description in SR 97, the ambition has been to include all relevant processes and interactions identified in the interaction matrices. The transfer of information from the interaction matrices to the Process Report/THMC-diagrams is documented in the same database as the interaction matrices.

Each of the 630 interactions in the matrices has been either:

A linked to the process in the Process Report where it is treated (76%)

B categorised as being related to the initial state of the sealed repository (and therefore by definition not treated in the Process Report) (7%)

C categorised as not included in the Process Report (17%)

The "interactions" in group B are not processes that form a part of the evolution of the sealed repository. They rather describe circumstances of importance to the initial state of the repository. An example is interaction 1.3a of the far-field matrix, describing the influence of the excavation method on the extent of the excavation disturbed zone (EDZ). The EDZ forms part of the initial state of the sealed repository, the starting point of the performance assessment.

Almost all interactions in group C are prioritised as "green" in the interaction matrices, i e as being of negligible importance in the performance assessment, see Section 3.3.

A few interactions have been linked to several headings, when the interaction is related to more than one heading in the Process Report. In case the interaction and the description in the Process Report is not in perfect accordance, comments are given on discrepancies.

5.1 Documentation in database

The coupling between the interaction matrices and the Process Report is documented in a database. The information in the matrices existed already in a database, which has been extended to also show the connection to the headings in the Process Report. The coupled database is available on a CD, in FileMaker Pro format, and the information can easily be searched.

From the "MAIN MENU" one can decide if one want to search how interactions in the matrix databases are covered by the Process Report or vice versa, see Figure 5-1. The information can be searched via the graphical description of the Interaction matrices or via the list of content in the Process Report, see Figure 5-2. A shortcut to directly find the coupling is via the "COUPLING MENU", see Figure 5-3. By pressing the button "View coupling of Process Report headings" one can for each heading in the Process Report directly see a list of related interactions, FEPs, in the different matrices, see Figure 5-4. The description of the interaction in the specific matrix is displayed when pressing the button for the desired matrix, (buffer = **B** , Near-field = **N** , Far-field = **F**).

All interactions in a selected matrix and the related headings in the Process Report are shown when pressing the button “View coupling of Interaction matrix” in the “COUPLING MENU”. Comments to the coupling between the matrix interactions and the headings in the Process Report are also given in this lay-out, see Figure 5-5.

Buttons in the different lay-outs make it easy to return to the “MAIN MENU” and the “COUPLING MENU”. For the more advanced user it is always possible to search information by using the Find-command for a specific field in the database.

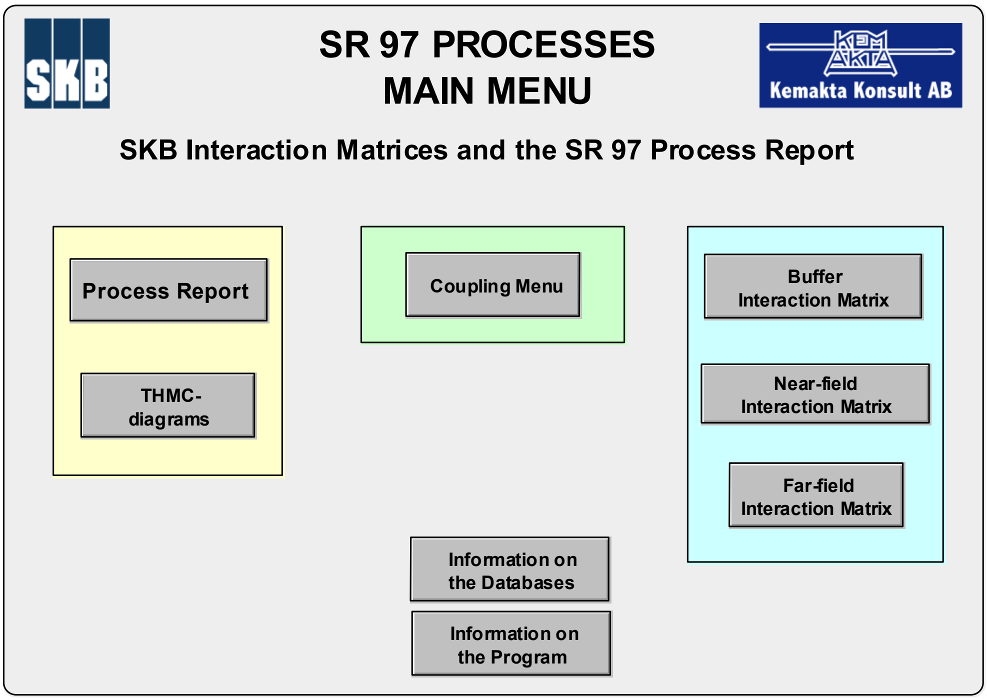

Figure 5-1 The main menu to access the Process Report and the Interaction matrices.

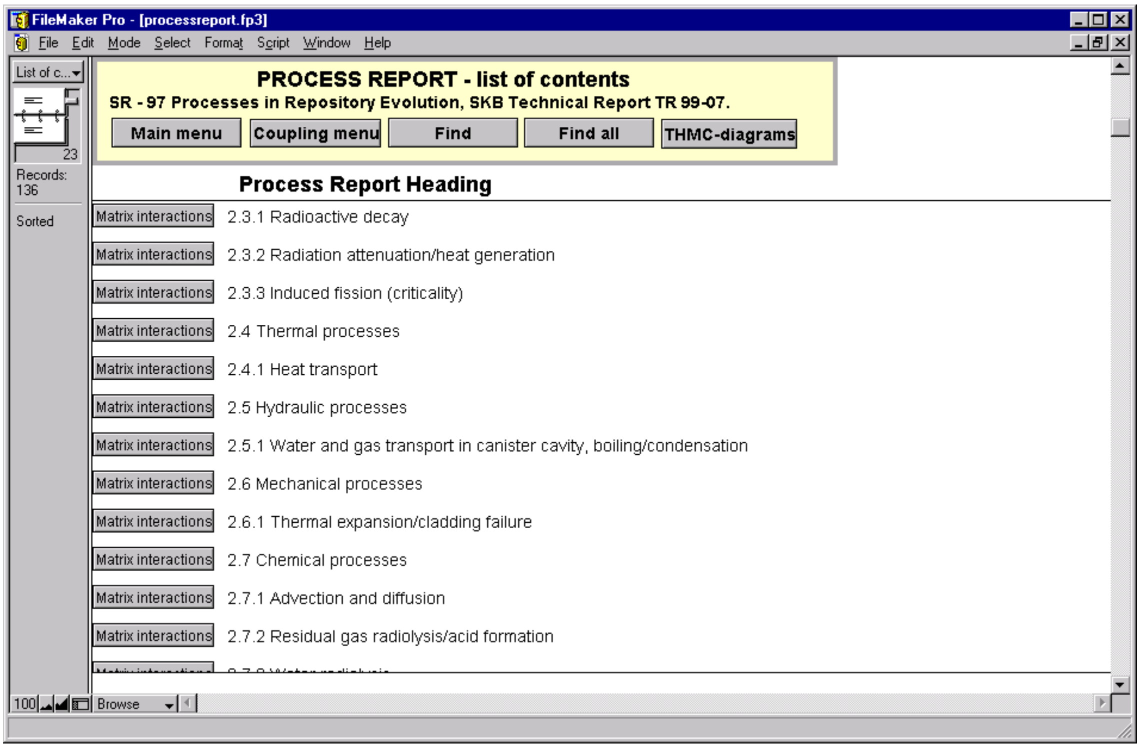

Figure 5-2 Menu to search interactions via Process Report headings.

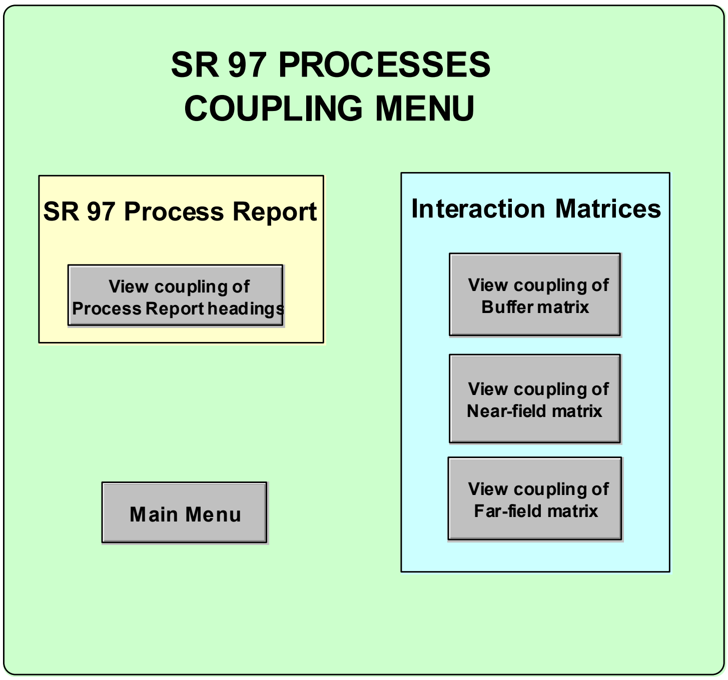

Figure 5-3 The "COUPLING MENU" to directly view the coupling between the Process Report and the Interaction matrices.

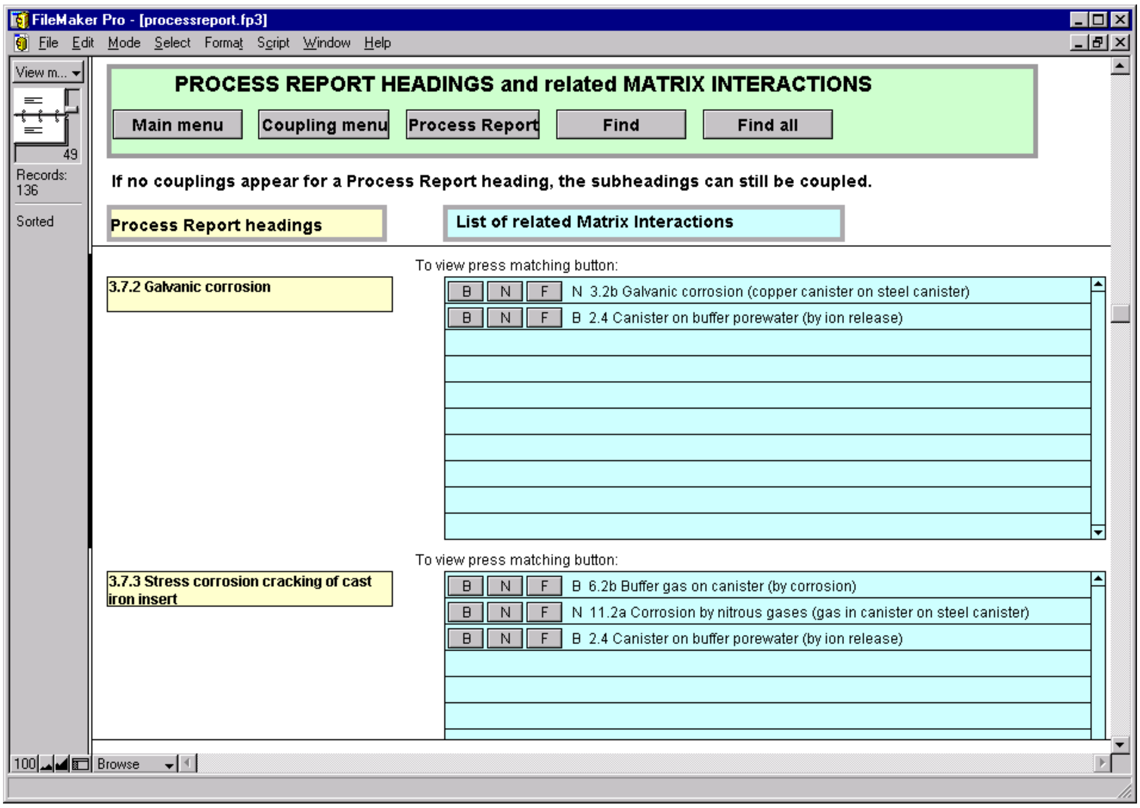

Figure 5-4 Coupling of Process Report headings to Interaction matrices.

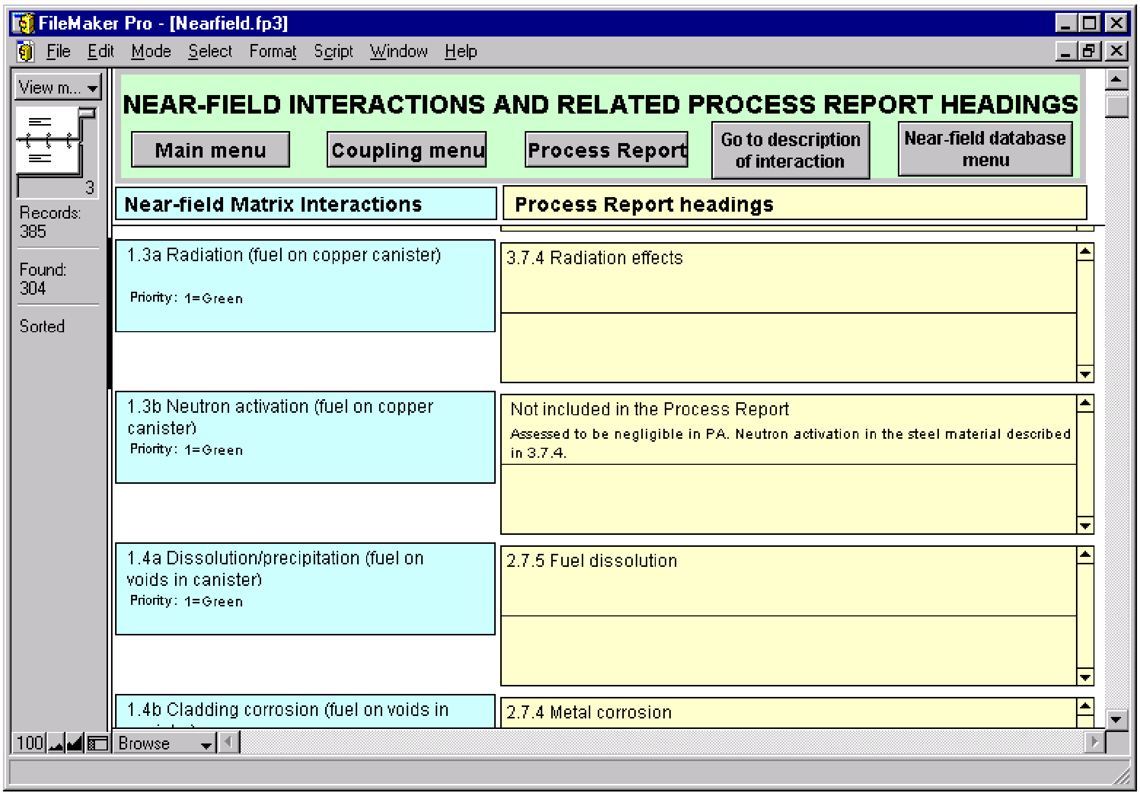

Figure 5-5 Coupling of near-field interactions to Process Report headings.

6 Concluding remarks

The role of Interaction matrices, THMC diagrams and FEP databases as tools in future assessments will be evaluated based on the experiences of SR 97 and its review. It can e g be noted that:

- Interaction matrices can be a useful structure when searching for interactions whereas THMC diagrams are probably better suited for the presentation of the system evolution in the performance assessment
- The structure of a THMC-diagram can be transferred to that of an interaction matrix by using the variables as diagonal elements and describing the processes and interactions in off-diagonal elements. The opposite transformation has been demonstrated in this report.
- THMC diagrams allow a clear distinction of interactions between different processes within a subsystem, e g the buffer, from interactions between subsystems e g in the buffer/rock interface. Some of the latter, which form boundary conditions for the processes within the subsystems, can be given a more detailed treatment in future versions of the Process Report.

In parallel with the work with interaction matrices, an SKB FEP database is under development. This work will continue and the completed FEP data base will be linked to the appropriate tools reported here. The information will also be linked to the international FEP database with similar information from different organisations and countries available via OECD/NEA (OECD/NEA, 1997).

Today's version of the Process Report is the first version of a report that will be revised prior to every safety report. The intention is to perform the first revision of the report after scrutiny of SR 97. The material will then also be linked to SKB's FEP database.

7 References

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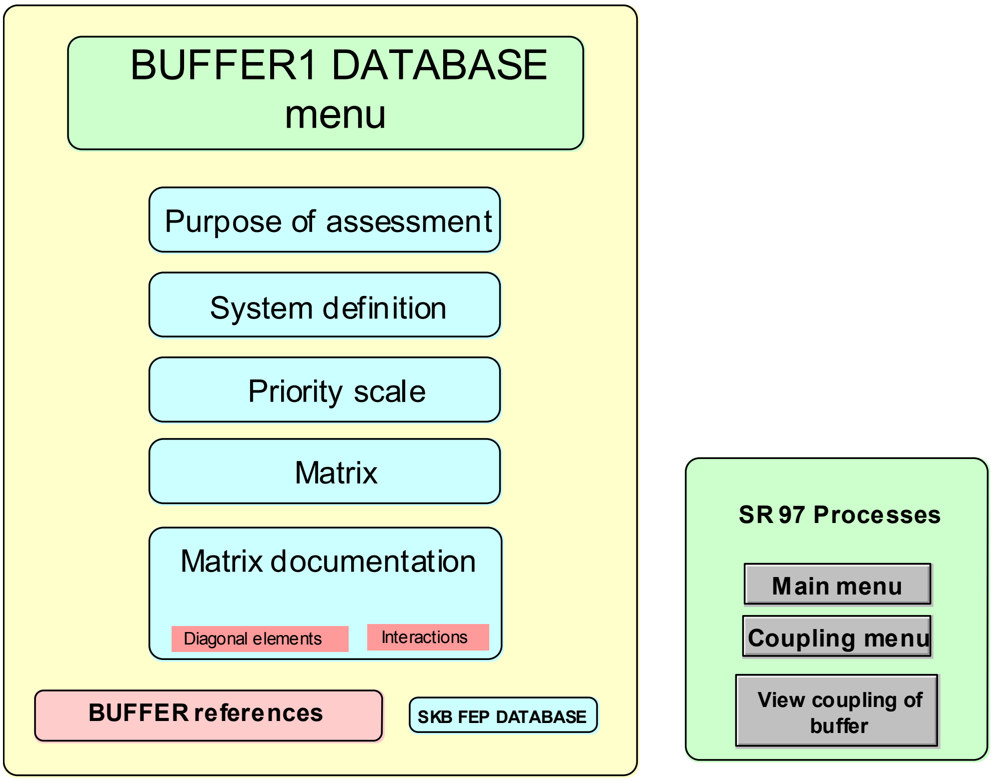
Appendix A: Buffer database



Contents

Group identification

The members of the group taking part in the construction of the matrix and the assignment of priorities to the interactions are given below.

Clay Technology: L Börgesson, R Pusch, H Hökmark, O Karnland
SKB: L Morén, P Sellin, C Svemar
Kemakta Konsult AB: K Skagius

Description of diagonal elements

1.1 Fuel

Spent fuel and metal components of the fuel, such as zircaloy cladding, fuel boxes, spacers, springs, grids etc of stainless steel and inconel in the canister.

The constituents are inclosed in the canister and assumed to be retained in it. Hence, no direct interaction with other repository components are considered, but radiation and gas emanating from the fuel are taken into account.

Interaction is primarily through radiation, which affects the canister (1.2), buffer smectite and non-smectite minerals /impurities (1.3, 1.5), buffer porewater (1.4) and groundwater chemistry (1.9). A second type of interaction is through heat production affecting the temperature conditions in the entire system (1.7).

2.2 Canister

Copper canister with an inner steel container in which the fuel is located. Both canister components are assumed to be intact except when gas generation is considered. Gamma radiation penetrating the canister is taken into account.

Interaction is with fuel (2.1), buffer (smectite and non-smectite/impurities, 2.3 and 2.5), buffer porewater (2.4), gas (contribution by corrosion, 2.6), temperature (heat transfer to surroundings, 2.7), and groundwater hydrology (geometrical restraint).

3.3 Smectite/buffer

Composition

The buffer consists of smectite-rich clay (bentonite) and accessory minerals and impurities, like non-smectite clay minerals (kaolinite, illite, chlorite) and rock-forming minerals (silicates, oxides, carbonates, sulphates and sulphides).

Conditions

The buffer is prepared in block form by compressing clay powder that may be purely natural (MX-80 Na smectite-rich bentonite) or soda-treated to Na form. The dry density of the buffer is in the interval 1500-2000 kg/m^3. The initial degree of water saturation is 45-85 % depending on the processing.

Properties

Buffer emplaced in the deposition holes absorbs water from the surroundings and ultimately becomes fully water saturated. In the saturation phase a number of processes take place that influence the performance both in early stages and long afterwards. After complete water saturation the buffer is characterized by a very low hydraulic conductivity and an ability to expand and exert a pressure on the surroundings that depends on the density and porewater chemistry and that can be several tens of MPa. The transport properties, like the hydraulic and gas conductivities and ion diffusivity, are largely controlled by the microstructure, which is affected by the density of the buffer and the chemical composition of the porewater.

Buffer in present context

In referring to physical and mechanical interactions the buffer material (3.3) is regarded as a whole, i.e. including porewater (4.4) and non-smectite minerals/impurities (5.5), but when chemical processes are referred to, only the smectite component is taken into account. Interaction is primarily with canister through pressurization (3.2) and chemical interaction (2.4) and through temperature effects (3.7).

4.4 Buffer porewater

Water in the buffer that is in contact with the canister, smectite minerals, other clay minerals, non-clay minerals and impurities (colloids and organics). It contains ions and occupies three sorts of voids: The interlamellar space within the stacks of smectite flakes ("pseudo- crystalline", organized water), water in the double-layer zone surrounding the stacks, and free water in voids larger than about 20 Å. The latter is termed "external", while the firstmentioned type of porewater is called "internal".

Interaction is primarily with buffer minerals through chemical effects (4.3, 4.5) and with the buffer as a whole through setting up pressures (swelling pressure and water pressure) in it and by percolating it (4.3). Temperature is interacting both with respect to chemical and physical effects (7.4).

5.5 Non-smectite minerals/impurities

Non-smectite clay minerals, such as illite, chlorite and kaolinite, non-clay silicate mineral such as quartz, feldspars, micas and heavy minerals, and non-silicate rock-forming minerals like carbonates, primarily calcite, oxides, hydroxides, phosphates, sulphates and sulphides. Also, colloids and organics belong to this group.

Interaction is primarily with the buffer porewater through chemical effects like dissolution (5.4) aided by temperature (7.5).

6.6 Gas

All gaseous phases in the buffer (not inside the canister), backfill and nearfield rock, such as trapped air and gases produced by corrosion (like hydrogen) and radiolysis (like oxygen), but excluding dissolved gas. Some of the interactions identified are only relevant for a corroding canister, i.e. assuming that water can penetrate the copper shield of the canister. Type, composition and amount of gas (at NPT), actual gas volume, gas pressure, critical gas pressure, gas flow, thermal properties of gas.

Interaction is primarily with the buffer through radiation effects (1.6), generating a gas pressure and gas-filled voids in the buffer (6.3). Indirect interaction is with the nearfield by bringing gas into the nearfield rock and thereby affecting the groundwater hydrology (6.8) and the backfill (6.12).

7.7 Temperature

Absolute temperature (Celcius or Kelvin), temperature evolution, temperature gradient, all expressed as functions of time after deposition of canisters in the respective hole. Temperature data for canisters, buffer, backfill and nearfield rock.

Interaction is primarily with the buffer through heating it and creating a temperature gradient across it. This affects chemical processes like dissolution of smectite (7.3) and other minerals (7.5) and physical properties like the hydraulic conductivity (7.3).

Other interactions of importance are with the groundwater hydrology (7.8) and the structure and performance of the nearfield rock (7.10).

8.8 Groundwater hydrology

Pressure, flow and properties of water contained in the backfill and nearfield rock. Density, viscosity, thermal properties and compressibility.

Interaction is of physical character, primarily with the buffer and backfill by affecting their saturation with water and exposure to erosion (8.3, 8.12), and with the nearfield rock through erosion (8.10).

9.9 Groundwater chemistry

Composition and properties of groundwater in the nearfield rock and of the porewater in the backfill in terms of the content and composition of dissolved species, colloids and microbes. Backfill porewater contains the three water types specified for the buffer, the interlamellar water being contained in the smectite component and the free water filling the voids between the stacks of smectite in the smectite component and all other voids in the system of between of the all sorts of minerals and impurities. The water in the rock ranges from strongly held capillary water in very fine voids and fissures to free water that moves under very low hydraulic gradients in channels in fractures. The chemical composition of the latter is controlled by the source while that in small voids is determined by its interaction with the confining minerals.

Interaction is primarily with the buffer porewater through (9.4) and with the nearfield rock through (9.10), reinforcements (9.11) and backfill (9.12).

10.10 Nearfield rock

Structure, stress conditions, geometry and properties of the rock surrounding the deposition holes and tunnels to a distance influenced by excavation (about 200 cubic meters per meter tunnel length). A most important feature of the rock as concerns interaction with buffer and backfill is the hydrology, which depends on the rock structure, and piezometric conditions. Also, its stability is of significance since it determines the behavior of the rock around deposition holes in the waste application phase as well as in a long-term perspective, i.e. when tectonics and glaciation are expected to play a role.

Physical interaction is primarily with the buffer through establishment of pressures (10.3, 10.4) and groundwater hydrology by being exposed to water pressure (10.8) and erosion (8.10). The major chemical interaction takes place indirectly with the buffer through groundwater chemistry (10.9) and buffer porewater (9.3, 9.4).

11.11 Reinforcements

Construction materials, like concrete, cement and bentonite grouts, cement paste, steel reinforcement (bars, bolts, supports), and asphalt. They are in contact with water contained in the backfill and nearfield rock.

Reinforcements are not planned to be in operation for more than the construction and waste application and backfilling phases. Their longevity is therefore not a major factor with the possible exception of grouts injected in fractures intersecting deposition holes.

Physical interaction is primarily with the nearfield rock and backfills through establishment of contact pressures (11.10, 11.12). Chemical interaction takes place indirectly through the groundwater with the nearfield rock (9.10) and the backfill (9.11, 9.12).

12.12 Backfill

The backfills considered consist of mixtures of smectitic clay and ballast or pure ballast. The clay component, which may correspond to 10 to 30 % by weight of the backfill, is expected to be of the same type as the buffer. The ballast will probably be rock excavated in conjunction with the construction of the repository. Crushing and grinding yields a grain size distribution that is suitable for achieving a high density with and without clay additives.

Physical interaction is primarily with the nearfield rock and reinforcements through establishment of contact pressures (12.10, 12.11). Chemical interaction takes place indirectly through the groundwater with the nearfield rock (10.9) and the backfill (11.9, 12.9).

List of identified interactions with priorities

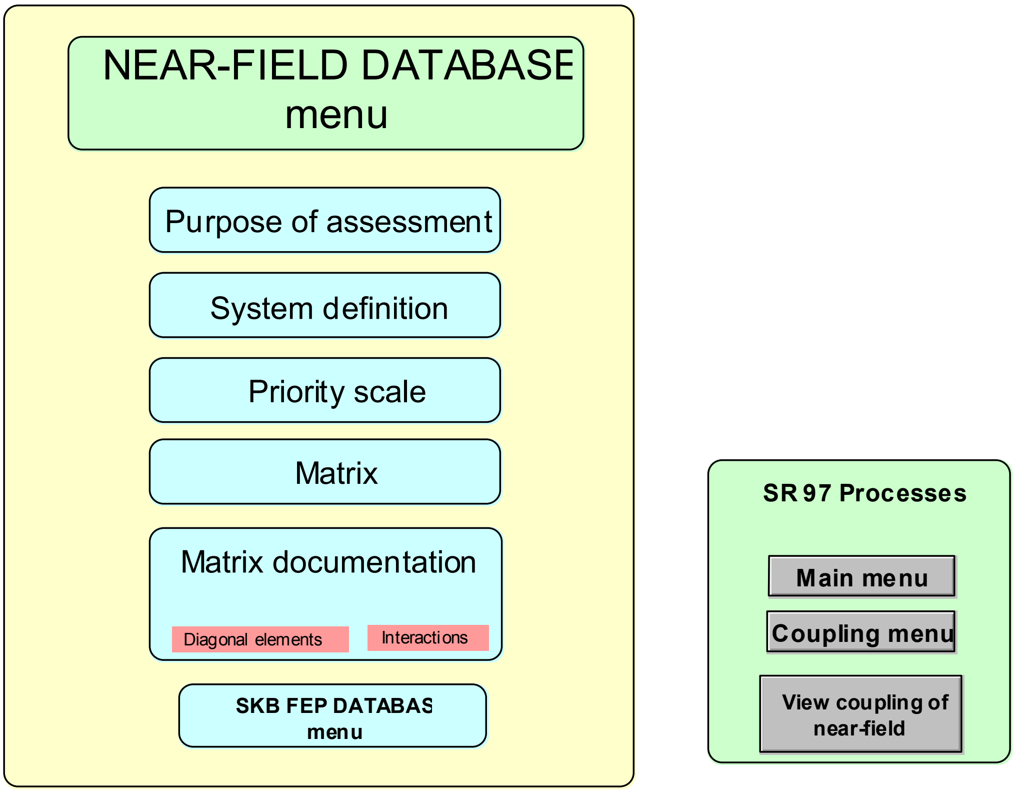
Element number and name	Priority
1.2 Fuel on canister (by radiation)	2=Yellow
1.3 Fuel on buffer smectite (by radiation)	1=Green
1.4 Fuel on buffer porewater (by radiolysis)	1=Green
1.5 Fuel on buffer non-smectite minerals/impurities in buffer (by radiation)	1=Green
1.6 Fuel on nearfield gas (by radiation)	4=Pink
1.7 Fuel on nearfield temperature (by radioactive decay)	3=Red
1.9 Fuel on groundwater chemistry in nearfield	1=Green
1.10 Fuel on nearfield rock (by radiation)	1=Green
1.11 Fuel on reinforcements (by radiation)	1=Green
1.12 Fuel on backfill (by radiation)	1=Green
2.1 Canister on fuel (by affecting confinement through changes in physical state)	3=Red
2.3a Canister on buffer (by affecting the density through pressurizing)	1=Green
2.3b Canister on buffer (by affecting the density through thermally induced geometrical changes)	1=Green
2.4 Canister on buffer porewater (by ion release)	2=Yellow
2.6 Canister on nearfield gas (by corrosion)	3=Red
2.7 Canister on nearfield temperature (by transfer of heat from fuel)	1=Green
2.8 Canister on groundwater hydrology (geo- metrical restraint)	1=Green
3.2a Buffer on canister (by affecting its position through swelling pressure anomalies)	3=Red
3.2b Buffer on canister (by affecting its shape through swelling pressure)	3=Red
3.2c Buffer on canister (by affecting position and shape through shearing)	3=Red
3.4a Buffer on buffer porewater (by ion diffusion)	3=Red
3.4b Buffer on buffer porewater (by affecting its physical state)	3=Red
3.4c Buffer on buffer porewater (by dissolution of smectite)	3=Red
3.4d Buffer on buffer porewater (by ion exchange)	1=Green
3.4e Buffer on buffer porewater (by producing colloids)	3=Red
3.4f Buffer on buffer porewater (by sorption)	1=Green
3.4g Buffer on buffer porewater (by flow)	1=Green
3.4h Buffer on buffer porewater (by affecting the pressure state)	4=Pink
3.5 Buffer on buffer non-smectite minerals/ impurities (by affecting their positions)	1=Green
3.6a Buffer on buffer gas (by capacity of storing gas)	3=Red
3.6b Buffer on buffer gas pressure (by release of gas)	3=Red
3.6c Buffer on buffer gas (by gas conductivity)	3=Red
3.7a Buffer on buffer temperature (by heat flow)	3=Red
3.7b Buffer on buffer temperature (by heat of wetting)	1=Green
3.8 Buffer on groundwater hydrology (by affecting flow in nearfield rock)	3=Red
3.10a Buffer on nearfield rock (by affecting the stability through swelling pressure)	3=Red
3.10b Buffer on nearfield rock (by affecting frac- ture aperture through swelling pressure)	3=Red
3.10c Buffer on nearfield rock (by self-sealing)	3=Red
3.11a Buffer on reinforcements (by destruction of cement grout in fractures in deposition holes)	1=Green
3.11b Buffer on reinforcements (by consolidation of bentonite grout in fractures in depostion holes)	1=Green
3.12 Buffer on backfill (by swelling pressure)	3=Red
4.2a Buffer porewater on canister (by corrosion)	3=Red
4.2b Buffer porewater on canister (by pressurizing canister)	3=Red
4.3a Buffer porewater on buffer (by producing swelling pressure and expandability)	3=Red
4.3b Buffer porewater on buffer (by dissolution of the smectite content)	3=Red
4.3c Buffer porewater on buffer smectite (by formation of smectite)	1=Green
4.3d Buffer porewater on buffer smectite (by ion-exchange)	3=Red
4.3e Buffer porewater on buffer smectite (by degrading and alterating it)	3=Red
4.3f Buffer porewater on buffer (by affecting the microstructural homogeneity)	3=Red
4.5a Buffer porewater on buffer non-smectite minerals/ impurities (by dissolution)	3=Red
4.5b Buffer porewater on buffer non-smectite minerals/impurities (by precipitation)	3=Red
4.6a Buffer porewater on buffer gas (by vapor pressure)	4=Pink
4.6b Buffer porewater on buffer gas (by dissolution of gas in porewater)	3=Red
4.6c Buffer porewater on buffer gas (by affecting the mobility of gas)	4=Pink
4.6d Buffer porewater on buffer gas (by affecting the pressure for release of gas)	4=Pink
4.6e Buffer porewater on buffer gas (by microbial activity)	1=Green

Element number and name	Priority
4.7a Buffer porewater on buffer temperature (by heat conductivity)	1=Green
4.7b Buffer porewater on buffer temperature (by heat of wetting)	1=Green
4.8 Buffer porewater on groundwater hydrology (by exerting pressure)	4=Pink
4.9 Buffer porewater on groundwater chemistry (by supplying or extracting dissolved species)	3=Red
4.10 Buffer porewater on nearfield rock (by exerting pressure on the rock)	1=Green
4.12 Buffer porewater on backfill (by affecting its porewater pressure)	4=Pink
5.2 Buffer non-smectite minerals/impurities on canister (by corroding contacting canister)	1=Green
5.3 Buffer non-smectite mineral/impurities on buffer smectite (by degrading contacting smectite)	1=Green
5.4a Buffer non-smectite minerals/impurities on buffer porewater (by being dissolved)	3=Red
5.4b Buffer non-smectite minerals/impurities on buffer porewater (by being precipitated)	3=Red
5.4c Buffer non/smectite minerals/impurities on buffer porewater (by forming colloids)	1=Green
5.7 Buffer non-smect. min./ impurities on buffer/canister temperature (by affect. heat conductivity)	1=Green
6.2a Buffer gas on canister (by pressurization)	1=Green
6.2b Buffer gas on canister (by corrosion)	2=Yellow
6.3a Buffer gas on buffer (by piping)	3=Red
6.3b Buffer gas on buffer (by affecting its homogeneity, i.a. through forming flow paths)	2=Yellow
6.3c Buffer gas on buffer (by affecting the hydration state)	2=Yellow
6.4a Buffer gas on buffer porewater (by being dissolved)	1=Green
6.4b Buffer gas on buffer porewater (by pressurizing)	1=Green
6.5 Buffer gas on buffer non-smectite minerals/impurities (by chemical reactions)	1=Green
6.7 Buffer gas on buffer/canister temperature (by thermal isolation)	4=Pink
6.8 Gas in nearfield rock on groundwater hydrology (by affecting the flow paths)	2=Yellow
6.9 Gas in nearfield rock on groundwater chemistry (by being dissolved)	3=Red
6.10a Gas in nearfield rock on nearfield rock (by affecting the degree of water saturation)	3=Red
6.10b Gas in nearfield rock on nearfield rock (by reaction with fracture minerals)	2=Yellow
6.11 Gas in nearfield rock and backfill on reinforcements (by pressurizing)	1=Green
6.12a Gas in backfill on backfill (by affecting the degree of water saturation)	4=Pink
6.12b Gas in backfill on backfill (by causing piping and erosion)	4=Pink
7.1 Temperature of fuel on fuel (by causing structural alteration)	1=Green
7.2a Temperature of canister on canister (by changing its size and shape)	1=Green
7.2b Temperature of canister on canister (by affecting its material structure)	1=Green
7.2c Temperature of canister on canister (by internal pressurizing)	1=Green
7.3a Temperature of buffer on buffer (by affecting the hydraulic conductivity)	1=Green
7.3b Temperature of buffer on buffer (by affecting its thermal properties)	1=Green
7.3c Temperature of buffer on buffer (by affecting its swelling pressure)	2=Yellow
7.3d Buffer temperature on buffer (by affecting its total pressure)	2=Yellow
7.3e Temperature of buffer on buffer (by affecting its shear strength)	2=Yellow
7.3f Temperature of buffer on buffer smectite (by affecting chemical equilibria)	3=Red
7.3g Temperature of buffer on buffer (by affecting the rate of alteration of the smectite)	3=Red
7.4a Temperature of buffer on buffer porewater (by redistribution)	4=Pink
7.4b Temperature of buffer on buffer porewater (by affecting the viscosity)	3=Red
7.4c Temperature of buffer on buffer porewater (by affecting the rate of chemical reactions)	3=Red
7.4d Temperature of buffer on buffer porewater (by determining the state of chemical equilibrium)	1=Green
7.4e Temperature of buffer temperature on buffer porewater (by affecting ion mobility)	1=Green
7.4f Temperature of buffer on buffer porewater (by affecting its pressure)	3=Red
7.5a Temperature of buffer on buffer non-smectite minerals/impurities (by affect. chemical equilibria)	3=Red
7.5b Temperature of buffer on buffer non-smectite miner./impurities (by affecting the rate of change)	1=Green
7.6a Temperature of buffer on buffer gas (by affecting its pressure)	2=Yellow
7.6b Temperature on buffer gas (by vapor transport)	4=Pink
7.6c Temperature of buffer on buffer gas (by affecting gas solubility)	4=Pink
7.8a Temperature of nearfield on groundwater hydrology (by groundwater convection)	2=Yellow
7.8b Temperature of nearfield on groundwater hydrology (by affecting the viscosity)	1=Green
7.9a Temperature of nearfield on groundwater chemistry (by affecting chemical equilibria)	1=Green
7.9b Temperature of nearfield on groundwater chemistry (by affecting the rate of chem. changes)	1=Green
7.10a Temperature of nearfield on nearfield rock (by affecting the structure)	2=Yellow
7.10b Temperature of nearfield on nearfield rock (by affecting the mechanical stability)	2=Yellow
7.10c Temperature of nearfield on nearfield rock (by affecting the rate of chemical changes)	2=Yellow
7.10d Temperature of nearfield on nearfield rock (by affecting chemical equlibria)	2=Yellow
7.11a Temperature of nearfield on reinforcements (by affecting their physical performance)	1=Green

Element number and name	Priority
7.11b Temperature of nearfield on reinforcements (by affecting chemical equilibria)	1=Green
7.11b Temperature of nearfield on reinforcements (by affecting the rate of chemical changes)	1=Green
7.12a Temperature of nearfield on backfill (by affecting chemical equilibria)	3=Red
7.12b Temperature of nearfield on backfill (by affecting the rate of chemical changes)	3=Red
7.12c Temperature of nearfield on backfill (by affecting its hydraulic conductivity)	1=Green
8.3a Groundwater hydrology on buffer smectite (by eroding smectite that has entered fractures)	2=Yellow
8.3b Groundwater hydrology on buffer (by providing water for saturation)	4=Pink
8.3c Groundwater hydrology on buffer (by affecting pressure heads and hence conditions for saturat.)	4=Pink
8.4 Groundwater hydrology on buffer porewater (by affecting its chemical composition)	1=Green
8.5 Groundwater hydrology on buffer non-smectite minerals/impurities (by erosion of buffer)	1=Green
8.6a Groundwater hydrology on nearfield gas (by aff. water pressure in the nearf. rock and backfill)	4=Pink
8.6b Groundwater hydrology on nearfield gas (by affect. gas migration in nearfield rock and backfill)	2=Yellow
8.7 Groundwater hydrology on nearfield temperature (by heat transport through convection)	1=Green
8.9a Groundwater hydrology on groundwater chemistry (by introducing water with diff. composition)	4=Pink
8.9b Groundwater hydrology on groundwater chemistry (by mixing and dilution)	3=Red
8.10a Groundwater hydrology on nearfield rock (by erosion)	1=Green
8.10b Groundwater hydrology on nearfield rock (by particle transport)	2=Yellow
8.11a Groundwater hydrology on reinforcements (by erosion)	1=Green
8.11b Groundwater hydrology on reinforcements (by pressurizing)	1=Green
8.12a Groundwater hydrology on backfill (by piping and erosion)	2=Yellow
8.12b Groundwater hydrology on backfill (by providing water for saturation)	2=Yellow
9.4 Groundwater chemistry on buffer porewater (by affecting its chemical composition)	3=Red
9.6 Groundwater chemistry on nearfield gas (by affecting its solubility)	3=Red
9.7 Groundwater chemistry on nearfield temp. (by affecting the heat conductivity of nearfield water)	1=Green
9.8a Groundwater chemistry on groundwater hydrology (by buoyancy effects)	1=Green
9.8b Groundwater chemistry on groundwater hydrology (by affecting water viscosity)	1=Green
9.10 Groundwater chemistry on nearfield rock (by affecting chemical equilibria)	3=Red
9.11a Groundwater chemistry on reinforcements (by affecting chemical equilibria)	2=Yellow
9.11b Groundwater chemistry on reinforcements (by cement maturation and gain in strength)	2=Yellow
9.12a Groundwater chemistry on backfill (by affecting chemical equilibria)	3=Red
9.12b Groundwater chemistry on backfill (by sorption)	3=Red
10.3a Nearfield rock on buffer (by affecting confining function)	3=Red
10.3b Nearfield rock on buffer (by imposing shear strain)	3=Red
10.3c Nearfield rock on buffer (by reducing its density through loss of buffer into fractures)	1=Green
10.3d Nearfield rock on buffer (by aff. its homogeneity through changes of the depos. hole geometry)	3=Red
10.3e Nearfield rock on buffer (by aff. its density through time-dep. convergence of the dep. holes)	2=Yellow
10.4 Nearfield rock on buffer porewater (by influence of earth currents)	1=Green
10.6a Nearfield rock on nearfield gas (by controlling the release of gas)	3=Red
10.6b Nearfield rock on nearfield gas (by storing gas)	2=Yellow
10.7 Nearfield rock on nearfield temperature (by aff. heat transport through its thermal conductivity)	4=Pink
10.8 Nearfield rock on groundwater hydrology (by its structural constitution)	3=Red
10.9a Nearfield rock on groundwater chemistry (by affecting chemical equilibria)	3=Red
10.9b Nearfield rock on groundwater chemistry (by influence of earth currents)	1=Green
10.9c Nearfield rock on groundwater chemistry (by colloid transport)	4=Pink
10.9d Nearfield rock on groundwater chemistry (by sorption of ions)	1=Green
10.9e Nearfield rock on groundwater chemistry (by matrix diffusion)	1=Green
10.11 Neafield rock on reinforcements (by imposing stress/strain)	2=Yellow
10.12a Nearfield rock on backfill (by providing confinement)	1=Green
10.12b Nearfield rock on backfill (by reduction of density through loss of backfill into fractures)	1=Green
11.2 Reinforcements on canister (by being lost in deposition holes)	1=Green
11.3 Reinforcements on buffer (by providing confinement)	1=Green
11.6a Reinforcements on nearfield gas (by producing gas)	1=Green
11.6b Reinforcement on nearfield gas (by storing gas)	1=Green
11.7 Reinforcements on nearfield temperature (by heat transport)	1=Green
11.8 Reinforcements on groundwater hydrology (by being permeable and affect. flow in nearfield rock)	3=Red
11.9 Reinforcements on groundwater chemistry (by dissol. and influence on chemical equilibria)	3=Red
11.10 Reinforcements on nearfield rock (by affecting its stability)	1=Green
11.12 Reinforcements on backfill (by providing confinement through lateral support)	2=Yellow

Element number and name	Priority
12.3 Backfill on buffer (by providing confinement)	3=Red
12.6a Backfill on nearfield gas (by affecting its pressure)	3=Red
12.6b Backfill on nearfield gas (by storing gas)	1=Green
12.7 Backfill on nearfield temperature (by heat flow)	1=Green
12.8 Backfill on groundwater hydrology (by distribution of flow in and through the backfill)	3=Red
12.9a Backfill on groundwater chemistry (by diss. of minerals and affecting chemical equilibria)	3=Red
12.9b Backfill on groundwater chemistry (by sorption)	1=Green
12.10a Backfill on nearfield rock (by affecting its structure through pressurizing)	2=Yellow
12.10b Backfill on nearfield rock (by affecting its stability through pressurizing)	3=Red
12.10c Backfill on nearfield rock (by penetrating into and sealing fractures)	2=Yellow
12.11 Backfill on reinforcements (by affecting their stability through pressurizing)	3=Red

Appendix B: Near-field database



Contents

Group identification

The members of the group taking part in the construction of the matrix and the assignment of priorities to the interactions are given below.

SKB: F Karlsson, P Sellin, L Werme
Kemakta Konsult AB: K Skagius, M Wiborgh
QuantiSci S.L: J Bruno

Description of diagonal elements

1.1 Fuel

This element includes the spent fuel and other metal parts such as zirkaloy cladding, fuel boxes, spacers, grids etc of stainless steel and inconel, in terms of amounts, material properties and radionuclide content at the time of repository closure and changes in these enteties with time.

2.2 Steel canisters

This element includes the steel canister in terms of dimensions, geometries and material properties at repository closure and changes in these enteties with time, as well as type and amount of radionuclides associated with solid phases of the steel canister materials.

The emplacements of initially damaged steel canisters are included in the definition.

3.3 Copper canister

This element includes the copper canister in terms of material properties at repository closure and changes in these enteties with time, as well as type and amount of radionuclides associated with solid phases of the canister materials.

At repository closure the copper canister can be defect e.g. due to damage of the copper canister during emplacement.

4.4 Voids in canister

This element refers to the initial void inside the steel canister and any voids between the inner steel canister and the outer copper canister in terms of dimensions, geometries at repository closure and changes in these enteties with time. The amount of water water and the water pressure in these voids are also included in this element.

5.5 Buffer

This element represents the bentonite buffer in the deposition holes in terms of dimensions and material properties after saturation of the repository and changes in these enteties with time. The initial dimensions and material properties like density and homogeneity are affected by the dimensions of the deposition holes, which also are included in this diagonalelement. The dimensions of the deposition holes are in turn dependent on the size of the canister and the properties of the buffer (e.g. composition, density, swelling ability).

The buffer definition includes clay- and non-clay minerals as well as impurities, and also amount of water, porewater pressure and swelling pressure. It also includes type and amount of radionuclides associated with solid phases of the buffer.

The initial properties of the buffer may be affected by the manufacturing of the buffer, prior to and during emplacement in the deposition holes.

6.6 Backfill

This element concerns the sand/bentonite backfill in the tunnels of the repository in terms of dimensions and material properties after saturation of the repository and changes in these enteties with time. It also includes type and amount of radionuclides associated with solid phases of the buffer. The swelling pressure and degree of saturation is included here, but the water pressure is defined in diagonal element 10.10 Water flow.

The dimensions and wall characteristics of the tunnels are also included in this element. These enteties put requirements on the geometry and material properties of the backfill (e.g. density and swelling ability), and backfill properties will influence dimensions and geometries of the tunnels.

7.7 Near-field rock

The near-field rock is the rock surrounding the repository which mechanically, hydrologically and geochemically is affected by the construction and the presence of the repository. It includes the The Excavation Damaged Zone, EDZ, defined as the zone extending around the deposition holes and the tunnels which is affected by the excavation process and subsequent mechanical processes. The definition includes the properties of the fractures, the rock matrix and the rock and fracture minerals in the near-field rock after saturation of the repository and changes in these enteties with time. However, water pressure and rock stresses are defined in diagonal elements 10.10 Water flow and 12.12 Near-field rock stresses, respectively.

The extent and magnitude of rock disturbance obtained during excavation is dependent on the mechanical stability of the near-field rock and the excavation method used, e.g. TBM or drilling/blasting. The initial properties of the near-field rock are also affected by processes taking place during construction and operation, such as calcite precipitation, iron and manganese precipitation and bacterial growth in the vicinity of the tunnel walls.

8.8 Construction materials

This element refers to construction materials in the repository, such as concrete grout, steel reinforcements and bentonite plugs, in terms of material properties after saturation of the repository and changes in these enteties with time. The amount and properties of these materials are affected by the choice of construction method.

The definition of this element also includes stray materials left in the repository at repository closure such as tools and material used for or in conjunction with the construction, operation and sealing of the repository.

9.9 Near-field water composition

This element represents the water composition in the canister interior, in the gap between steel and copper canister, in the engineered barriers and in the near-field rock. It includes main constituent, redox sensitive elements, pH, Eh, fulvic and humic acids, bacteria, colloids and dissolved gases which may affect the performance of the barriers and radionuclide migration in the near field.

10.10 Near-field water flow

This element concerns the water flow in the near-field after saturation of the repository. It includes magnitude, direction and distribution of water movement and the water pressure in the near-field rock and tunnel backfill. It also includes water movement in the buffer and water intrusion and expulsion in a failed canister.

The initial hydrostatic pressure is detemined by the depth of the repository.

11.11 Near-field gas

This element refers to all kind of gases, including radioactive gas, present or generated in the canister, the buffer, the backfill and the near-field rock, but not to dissolved gases. It includes gas amounts and composition, distribution of gas, and also gas pressure.

Blasting of the tunnels will generate gas which may enter the nearby rock, and ventilation of the repository during construction and operation will dry out the nearby rock and air can diffuse into the rock. If present after closure and saturation of the repository, these gases will affect the initial amount and composition of the near-field gas.

12.12 Near-field temperature

This element defines the temperature in the fuel, the canister, the engineered barriers, as well as in the near-field rock after saturation of the repository. These temperatures are affected by the temperature at repository closure which in turn is dependent on the depth of the repository and the ventilation of the repository during construction and operation.

13.13 Near-field rock stresses

This element refers to rock stresses in the near-field rock around the deposition holes and tunnels. Rock stresses refer to the "total stresses" (effective stress + porewater pressure) which can be measured in-situ.

14.14 Radionuclides in near-field water

This element refers to radionuclides in the water in the canister, the buffer, the tunnel backfill and the near-field rock. It includes dissolved radionuclides, colloidal/particulate fractions of radionuclides in the water and dissolved radioactive gases in terms of types, amounts and distribution.

15.15 Far-field

This element constitutes the boundary conditions to the near-field, which is the focus of this interaction matrix. The element represents the far-field in terms of the rock itself, far-field temperature, gas in the rock, groundwater hydrology, the chemistry of the groundwater as well as radionuclides in the water.

The rock includes the natural fracture system and fracture zones of different magnitude, the rock matrix and rock and fracture minerals, in terms of physical, mechanical, thermal and geochemical properties as well as rock stresses.

Gas in the rock refers to natural and waste generated gases of all kinds in the rock matrix and in the natural fracture system, including radioactive gases, but not dissolved gases. Gas pressure is also included.

The far-field hydrology includes the groundwater movement in terms of magnitude, direction and distribution, as well as the groundwater pressure.

The chemistry of the groundwater refers to the composition of the groundwater in the far-field rock in terms of main constituents, redox sensitive elements, pH, Eh, fulvic and humic acids, bacteria, colloids and dissolved gases.

Radionuclides in the water in the far-field includes dissolved radionuclides, colloidal/particulate fractions of radionuclides in the water and dissolved radioactive gases in terms of types, amounts and distribution.

List of identified interactions with priorities

Element name and number	Priority
1.2a Radiation (fuel on steel canister)	1=Green
1.2b Neutron activation (fuel on steel canister)	1=Green
1.3a Radiation (fuel on copper canister)	1=Green
1.3b Neutron activation (fuel on copper canister)	1=Green
1.4a Dissolution/precipitation (fuel on voids in canister)	1=Green
1.4b Cladding corrosion (fuel on voids in canister)	1=Green
1.5 Radiation (fuel on buffer)	1=Green
1.6 Radiation (fuel on backfill)	1=Green
1.7 Radiation (fuel on near-field rock)	1=Green
1.8 Radiation (fuel on construction materials)	1=Green
1.9a Radiolysis (fuel on water composition outside the canister)	1=Green
1.9b Radiolysis (fuel on water composition inside canister)	3=Red
1.9c Oxidant sink (fuel on water composition in canister)	3=Red
1.9d Fuel dissolution (fuel on water composition in canister)	3=Red
1.9e Cladding corrosion (fuel on water composition in the canister)	1=Green
1.11a Helium production (fuel on gas inside canister)	1=Green
1.11b Radiolysis (fuel on gas inside canister)	3=Red
1.11c Radiolysis (fuel on gas outside canister)	1=Green
1.11d Cladding corrosion (fuel on gas inside canister)	1=Green
1.11e Radioactive gas (fuel on radioactive gas in canister)	3=Red
1.12 Decay heat (fuel on near-field temperature)	3=Red
1.14a Dissolution/precipitation (fuel on radionuclides in water in canister)	3=Red
1.14b Instant release (fuel on radionuclides in water in canister)	3=Red
1.14c Cladding corrosion (fuel on water in canister)	3=Red
2.1 Confinement (steel canister on fuel)	3=Red
2.3 Yawning (steel canister on copper canister)	3=Red
2.4a Corrosion products (steel canister on voids in canister)	3=Red
2.4b Void size (steel canister on voids in canister)	3=Red
2.9 Corrosion (steel canister on water composition in canister)	3=Red
2.10 Integrity (steel canister on water flow through canister)	3=Red
2.11a Corrosion gas (steel canister on gas in canister)	3=Red
2.11b Gas release (steel canister on gas in canister)	1=Green
2.12 Heat transport (steel canister on temperature in near-field)	1=Green
2.14a Sorption/desorption (steel canister on radionuclides in water in canister)	2=Yellow
2.14b Diffusion (steel canister on radionuclides in near-field water)	3=Red
2.14c Colloid filter (steel canister on radionuclides in near-field water)	1=Green
2.14d Dissolution (steel canister on radionuclides in the water in the canister)	1=Green
3.2a Confinement (copper canister on steel canister)	3=Red
3.2b Galvanic corrosion (copper canister on steel canister)	1=Green
3.4 Void size (copper canister on voids in canister)	3=Red
3.5a Density (canister on buffer)	1=Green
3.5b Expansion/compression (copper canister on buffer)	1=Green
3.9 Corrosion (copper canister on water composition in buffer and in canister)	1=Green
3.10a Integrity (copper canister on water flow through canister)	3=Red
3.10b Intersects flowpaths (copper canister on water flow in near-field rock)	1=Green
3.11 Gas release (copper canister on gas inside canister)	3=Red
3.12 Heat transport (copper canister on near-field temperature)	1=Green
3.14a Sorption/desorption (copper canister on radionuclides in the water in the canister)	1=Green
3.14b Diffusion (copper canister on radionuclides in near-field water)	3=Red
3.14c Colloid filter (copper canister on radionuclides in near-field water)	1=Green
3.14d Dissolution (copper canister on radionuclides in the water in the canister)	1=Green
4.1a Fuel alteration (voids in canister on fuel)	3=Red
4.1b Fuel dissolution/precipitation (voids in canister on fuel)	3=Red
4.1c Cladding corrosion (voids in canister on fuel)	1=Green
4.1d Solubility (voids in canister on fuel)	1=Green
4.2a External corrosion (voids in canister on steel canister)	3=Red
4.2b Internal corrosion (voids in canister on steel canister)	1=Green
4.2c Solubility (voids in canister on steel canister)	1=Green
4.3 Mechanical stability (voids in canister on copper canister)	1=Green

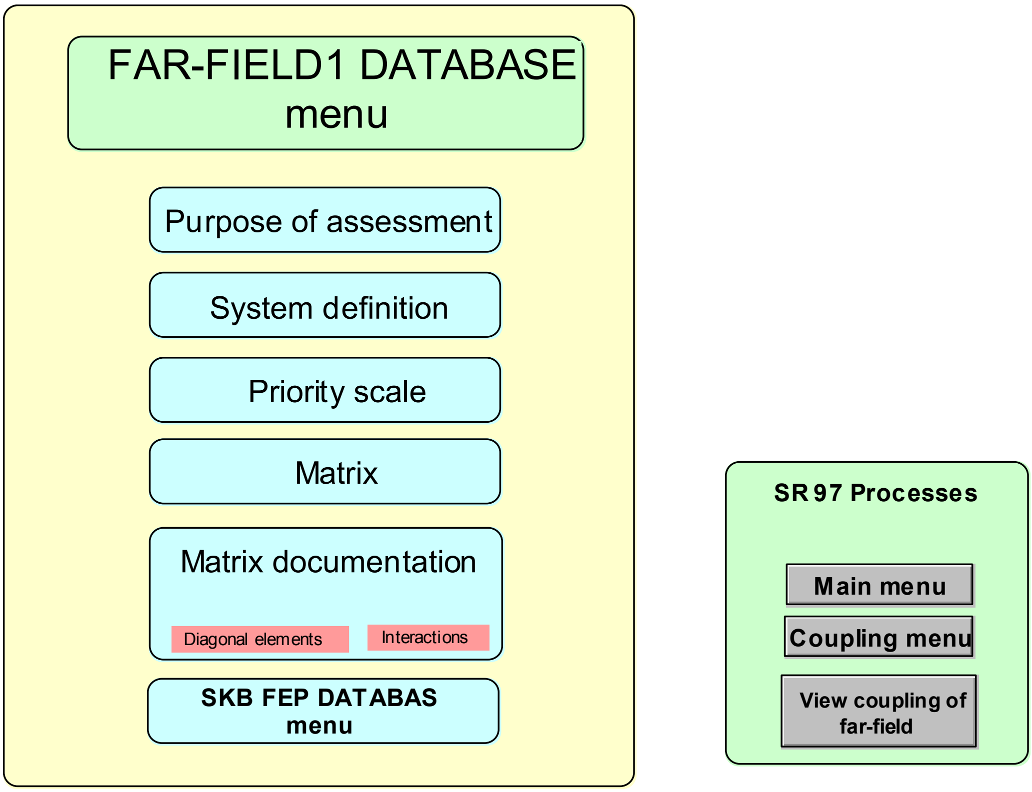
Element name and number	Priority
4.5 Buffer intrusion (steel canister on buffer)	1=Green
4.9a Solubility (voids in canister on water composition in canister)	1=Green
4.9b Extent of reactions (voids in canister on water composition in canister)	3=Red
4.10 Internal water pressure (voids in canister on near-field water flow)	1=Green
4.11 Gas expansion/compression (voids in canister on gas in canister)	1=Green
4.12 Heat transport (voids in canister on near-field temperature)	1=Green
4.14a Solubility (voids in canister on radionuclides in water in canister)	1=Green
4.14b Extent of reactions (voids in canister on radionuclides in water in canister)	3=Red
4.14c Volume effect on IRF (voids in canister on radionuclides in water in canister)	3=Red
5.3a Confinement (buffer on copper canister)	3=Red
5.3b Swelling pressure (buffer on copper canister)	1=Green
5.3c Shear (buffer on copper canister)	3=Red
5.3d SCC (buffer on copper canister)	3=Red
5.3e Porewater pressure (hydrostatic pressure) (buffer on copper canister)	3=Red
5.4 Buffer intrusion (buffer on voids in canister)	1=Green
5.6 Swelling pressure (buffer on backfill)	3=Red
5.7 Intrusion (buffer on near-field rock)	3=Red
5.8 Mechanical impact (buffer on construction materials)	1=Green
5.9a Colloid source (buffer on water composition in near-field rock)	3=Red
5.9b Dissolution/precipitation (buffer on water composition in near-field)	3=Red
5.9c Ion-exchange/sorption (buffer on near-field water composition)	1=Green
5.9d Diffusion (buffer on near-field water composition)	3=Red
5.9e Colloid filter (buffer on porewater composition)	3=Red
5.9f Water activcity (buffer on buffer porewater)	3=Red
5.9g Solubility (buffer on composition of buffer porewater)	1=Green
5.10a Intersects flow paths (buffer on water flow in near-field rock)	3=Red
5.10b Flow in buffer (buffer on water flow in buffer)	3=Red
5.10c Water exchange, canister (buffer on water flow through canister)	3=Red
5.11 Gas flow in buffer (buffer properties on gas in buffer)	3=Red
5.12 Heat transport (buffer on temperature in canister and buffer)	3=Red
5.13a Swelling pressure (buffer on near-field rock stresses)	3=Red
5.13b Porewater pressure (buffer on near-field rock stresses)	1=Green
5.14a Ion-exchange, sorption (buffer on radionuclides in buffer porewater)	3=Red
5.14b Diffusion (buffer on radionuclides in near-field water)	3=Red
5.14c Colloid filter (buffer on radionuclides in near-field water outside the buffer)	3=Red
5.14d Solubility (buffer on radionuclides in buffer porewater)	1=Green
5.14e Dissolution (buffer on radionuclides in buffer porewater)	1=Green
6.5 Confinement (backfill on buffer)	3=Red
6.7 Intrusion (backfill on near-field rock)	1=Green
6.8 Mechanical impact (backfill on construction materials)	1=Green
6.9a Colloid source (backfill on near-field water composition)	1=Green
6.9b Dissolution/precipitation (backfill on near-field water composition)	1=Green
6.9c Ion-exchange/sorption (backfill on backfill water composition)	1=Green
6.9d Diffusion (backfill on near-field water composition)	1=Green
6.9e Colloid filter (backfill on near-field water composition)	1=Green
6.10 Local hydrology (backfill on near-field water flow)	3=Red
6.11 Gas flow (backfill on near-field gas)	1=Green
6.12 Heat transport (backfill on near-field temperature)	1=Green
6.13a Swelling pressure (backfill on near-field rock stresses)	3=Red
6.13b Tunnel dimensions (backfill on near-field rock stresses)	3=Red
6.14a Ion-exchange, sorption (backfill on radionuclides in near-field water)	3=Red
6.14b Diffusion (backfill on radionuclides in near-field water)	3=Red
6.14c Colloid filter (backfill on radionuclides in near-field water)	1=Green
6.14d Dissolution (backfill on radionuclides in backfill water)	1=Green
7.5a Rock displacement (near-field rock on buffer)	3=Red
7.5b Confinement (near-field rock on buffer)	3=Red
7.5c Density decrease (near-field rock on buffer)	1=Green
7.6a Rock movements (near-field rock on backfill)	1=Green
7.6b Confinement (near-field rock on backfill)	3=Red
7.6c Density decrease (near-field rock on backfill)	1=Green
7.8 Reinforcements (near-field rock on construction materials)	1=Green
7.9a Sorption (near-field rock on water composition in near-field rock)	1=Green

Element name and number	Priority
7.9b Matrix diffusion (near-field rock on water composition in near-field rock)	1=Green
7.9c Dissolution/precipitation (near-field rock on water composition in near-field rock)	3=Red
7.9d Earth currents (near-field rock on near-field water composition)	1=Green
7.9e Molecular diffusion (near-field rock on water composition in near-field rock)	1=Green
7.10 Local hydrology (near-field rock on near-field water flow)	3=Red
7.11 Gas flow (near-field rock on near-field gas)	3=Red
7.12 Heat transport (near-field rock on near-field temperature)	1=Green
7.13 Stress relaxation (near-field rock on near-field rock stresses)	1=Green
7.14a Fracture sorption (near-field rock on radionuclides in near-field water)	3=Red
7.14b Matrix diffusion (near-field rock on radionuclides in near-field water)	3=Red
7.14c Matrix sorption (near-field rock on radionuclides in near-field water)	3=Red
7.14d Molecular diffusion (near-field rock on radionuclides in near-field water)	1=Green
7.14e Dissolution (near-field rock on radionuclides in near-field water)	1=Green
8.3 Mechanical impact (construction materials on copper canister)	1=Green
8.5 Confinement (construction materials on buffer)	1=Green
8.6 Confinement (construction materials on backfill)	1=Green
8.7 Mechanical support (rock reinforcements on near-field rock)	1=Green
8.9a Alteration (construction materials on near-field water composition)	3=Red
8.9b Stray materials (construction materials on near-field water composition)	3=Red
8.10 Flow pattern (construction materials on near-field water flow)	2=Yellow
8.11a Corrosion gases (construction materials on near-field gas)	1=Green
8.11b Gas inclusion (construction materials on near-field gas)	1=Green
8.12 Heat transport (construction materials on near-field temperature)	1=Green
8.14a Sorption/desorption (construction materials on radionucl. in near-field water)	1=Green
8.14b Diffusion (construction materials on radionuclides in near-field water)	1=Green
8.14c Dissolution (construction materials on radionuclides in near-field water)	1=Green
9.1a Fuel alteration (water composition in canister on fuel matrix)	3=Red
9.1b Fuel dissolution/precipitation (water composition in canister on fuel)	3=Red
9.1c Cladding corrosion (water composition in canister on fuel cladding)	1=Green
9.2 Corrosion (water composition in canister on steel canister)	3=Red
9.3 Corrosion (composition of buffer porewater on copper canister)	3=Red
9.5a Ion-exchange/sorption (composition of buffer porewater on buffer)	3=Red
9.5b Dissolution/precipitation (composition of buffer porewater on buffer)	3=Red
9.5c Microstructural constitution (composition of buffer porewater on buffer)	3=Red
9.5d Illitization (composition of buffer porewater on buffer)	3=Red
9.6a Ion exchange/sorption (composition of backfill water on backfill)	1=Green
9.6b Dissolution/precipitation (composition of backfill water on backfill)	1=Green
9.6c Swelling (composition of backfill water on backfill)	1=Green
9.7a Fracture alteration (near-field water composition on near-field rock)	1=Green
9.7b Rock alteration (near-field water composition on near-field rock)	1=Green
9.8a Dissolution/corrosion (near-field water composition on construction materials)	1=Green
9.8b Maturation (near-field water composition on construction materials)	1=Green
9.10 Density, viscosity (near-field water composition on near-field water flow)	1=Green
9.11a Gas dissolution (near-field water composition on near-field gas)	1=Green
9.11b Microbial activity (near-field water composition on near-field gas)	1=Green
9.11c Chemical reactions (near-field water composition on near-field gas)	1=Green
9.12 Heat transport (near-field water composition on near-field temperature)	1=Green
9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)	3=Red
9.14b Sorption/desorption (near-field water comp. on radionucl. in near-field water)	3=Red
9.14c Colloid transport (near-field water comp. on radionucl. in near-field water)	3=Red
9.14d Dissolution of radioactive gas (n-f wat. comp. on radionucl. in near-field water)	1=Green
09.15 Exchange (near-field water comp. on far-field water comp.)	3=Red
10.4 Intrusion/expulsion	3=Red
10.5a Pressure (near-field water flow on buffer)	1=Green
10.5b Erosion (near-field water flow on buffer)	1=Green
10.6a Erosion (near-field water flow on backfill)	1=Green
10.6b Solubility (near-field water flow on backfill)	1=Green
10.7a Erosion/sedimentation (near-field water flow on near-field rock)	1=Green
10.7b Solubility (near-field water flow on near-field rock)	1=Green
10.8a Erosion (near-field water flow on construction materials)	1=Green
10.8b Solubility (near-field water flow on construction materials)	1=Green
10.8c Grouting (near-field water flow on construction materials)	1=Green

Element name and number	Priority
10.9a Transport of species (near-field water flow on near-field water composition)	3=Red
10.9b Solubility (near-field water flow on near-field water composition)	1=Green
10.11a Pressure (near-field water flow on near-field gas)	3=Red
10.11b Gas dissolution (near-field water flow on near-field gas)	3=Red
10.11c Two-phase flow (near-field water flow on near-field gas)	1=Green
10.12 Heat convection (near-field water flow on near-field temperature)	1=Green
10.13 Effective stress (near-field water flow on near-field rock stresses)	1=Green
10.14a Transport of dissolved RN (n-f water flow on radionucl. in near-field water)	3=Red
10.14b Transport of dissolved gas (n-f water flow on radionucl. in near-field water)	1=Green
10.14c Solubility (near-field water flow on radionuclides in near-field water)	1=Green
10.15 Hydraulic gradient (near-field water flow on far-field water flow)	3=Red
11.1a Cladding corrosion (gas in canister on fuel)	1=Green
11.1b H2 catalysis (gas in canister on fuel)	2=Yellow
11.2a Corrosion by nitrous gases (gas in canister on steel canister)	1=Green
11.2b Corrosion by water vapour (gas in canister on steel canister)	3=Red
11.2c Hydrogen pressure (gas in canister on steel canister)	1=Green
11.2d Internal impact (gas in canister on steel canister)	1=Green
11.2e External impact (gas outside steel canister on steel canister)	1=Green
11.3a Corrosion (near-field gas on copper canister)	1=Green
11.3b Internal impact (gas in canister on copper canister)	1=Green
11.5a Piping (gas in buffer on buffer)	3=Red
11.5b Flotation (gas in buffer on buffer)	2=Yellow
11.5c Porewater pressure (gas inside buffer on buffer)	1=Green
11.5d Dehydration (gas inside buffer on buffer)	2=Yellow
11.5e Chemical reactions (gas in buffer on buffer)	1=Green
11.6a Dehydration (gas in backfill on backfill)	1=Green
11.6b Piping (gas in backfill on backfill)	1=Green
11.7a Dehydration (gas in near-field rock on near-field rock)	1=Green
11.7b Chemical reactions (gas in near-field rock on near-field rock)	1=Green
11.7c Fractures (gas in near-field rock on near-field rock)	1=Green
11.8 Mechanical impact (near-field gas on construction materials)	1=Green
11.9a Gas dissolution (near-field gas on near-field water composition)	3=Red
11.9b Radiolysis (gas in canister on water composition in canister)	3=Red
11.10a Displacement (near-field gas on near-field water flow)	3=Red
11.10b Two-phase flow (near-field gas on near-field water flow)	1=Green
11.12 Heat transport (near-field gas on near-field temperature)	1=Green
11.14a Colloids on gas bubbles (near-field gas on radionuclides in near-field water)	2=Yellow
11.14b Dissolution of radioactive gas (near-field gas on radionucl. in n-f water)	1=Green
11.15a Gas flow (near-field gas on far-field gas)	3=Red
11.15b Composition (near-field gas on far-field gas)	3=Red
11.15c Radioactive gas (near-field gas on far-field gas)	3=Red
12.1a Structural/chemical alteration (temperature in canister on fuel)	1=Green
12.1b Kinetics (temperature in canister on fuel)	1=Green
12.1c Equilibria (near-field temperature on fuel)	1=Green
12.1d Volatility and migration (temperature in canister on fuel)	1=Green
12.1e Expansion/contraction (temperature in canister on fuel cladding)	1=Green
12.2a Expansion/contraction (temperature in canister on steel canister)	1=Green
12.2b Mechanical strength (temperature in canister on steel canister)	1=Green
12.2c Kinetics (temperature in canister on steel canister)	1=Green
12.2d Equlibria (temperature in canister on steel canister)	1=Green
12.3a Expansion/contraction (temperature in canister on copper canister)	1=Green
12.3b Mechanical strength (temperature in canister on copper canister)	1=Green
12.3c Kinetics (temperature in canister on copper canister)	1=Green
12.3d Equlibria (temperature in canister on copper canister)	1=Green
12.4 Phase changes (temperature in canister on voids in canister)	1=Green
12.5a Kinetics (temperature in buffer on buffer)	3=Red
12.5b Equlibria (temperature in buffer on buffer)	3=Red
12.5c Hydraulic conductivity (temperature in buffer on buffer)	1=Green
12.5d Swelling pressure (temperature in buffer on buffer)	1=Green
12.5e Expansion/contraction (temperature in buffer on buffer)	1=Green
12.5f Porewater pressure (temperature in buffer on buffer)	1=Green
12.5g Thermal properties (tmperature in buffer on buffer)	1=Green
12.5h Shear strength (temperature in buffer on buffer)	1=Green

Element name and number	Priority
12.6a Kinetics (temperature in backfill on backfill)	1=Green
12.6b Equilibria (temperature in backfill on backfill)	1=Green
12.6c Hydraulic conductivity (temperature in buffer on buffer)	1=Green
12.7a Fracturing (temperature in near-field rock on near-field rock)	2=Yellow
12.7b Fracture aperture (temperature in near-field rock on near-field rock)	2=Yellow
12.7c Kinetics (temperature in near-field rock on near-field rock)	1=Green
12.7d Equlibria (temperature in near-field rock on near-field rock)	1=Green
12.7e Thermal conductivity (temperature in near-field rock on near-field rock)	1=Green
12.8a Expansion/contraction (near-field temperature on construction materials)	1=Green
12.8b Kinetics (near-field temperature on construction materials)	1=Green
12.8c Equilibria (near-field temperature on construction materials)	1=Green
12.9a Kinetics (near-field temperature on near-field water composition)	1=Green
12.9b Equilibria (near-field temperature on near-field water composition)	2=Yellow
12.9c Phase changes (near-field temperature on near-field water comp.)	1=Green
12.9d Diffusion (near-field temperature on near-field water composition)	1=Green
12.9e Gradient transport (near-field temperature on near-field water comp.)	1=Green
12.10a Convection cells (near-field temperature on near-field water flow)	1=Green
12.10b Viscosity (near-field temperature on near-field water flow)	1=Green
12.11a Expansion/compression (near-field temperature on near-field gas)	1=Green
12.11b Gas dissolution (near-field temperature on near-field gas)	1=Green
12.14a Kinetics (near-field temperature on radionuclides in near-field water)	1=Green
12.14b Equilibria (near-field temperature on radionuclides in near-field water)	2=Yellow
12.14c Diffusion (near-field temperature on radionuclides in near-field water)	1=Green
12.14d Gradient transport (near-field temperature on radionuclides in n-f water)	1=Green
12.15 Heat transfer (near-field temperature on far-field temperature)	1=Green
13.5a Rock displacement (near-field rock stresses on buffer)	3=Red
13.5b Rock creep (near-field rock stresses on buffer)	2=Yellow
13.6a Rock displacement (near-field rock stresses on backfill)	1=Green
13.6b Rock creep (near-field rock stresses on backfill)	1=Green
13.7a Fracturing (near-field rock stresses on near-field rock)	3=Red
13.7b Fracture aperture (near-field rock stresses on near-field rock)	3=Red
13.8 Deformations (near-field rock stresses on construction materials)	1=Green
13.15 Stress (near-field rock stresses on far-field rock stresses)	1=Green
14.1 Dissolution/precipitation (radionuclides in water in canister on fuel)	3=Red
14.2 Contamination (radionuclides in water in canister on steel canister)	1=Green
14.3 Contamination (radionuclides in near-field water on copper canister)	1=Green
14.5a Contamination (radionuclides in buffer porewater on buffer)	1=Green
14.5b Radiation effects (radionuclides in buffer porewater on buffer)	1=Green
14.6a Contamination (radionuclides in backfill water on backfill)	1=Green
14.6b Radiation effects (radionuclides in backfill water on backfill)	1=Green
14.7a Contamination (radionuclides in water in near-field rock on near-field rock)	1=Green
14.7b Radiation effects (radionuclides in water in near-field rock on near-field rock)	1=Green
14.8a Contamination (radionuclides in near-field water on construction materials)	1=Green
14.8b Radiation effects (radionuclides in near-field water on construction materials)	1=Green
14.9a Contamination (radionuclides in near-field water on near-field water comp.)	1=Green
14.9b Redox front (radionuclides in near-field water on near-field water comp.)	3=Red
14.9c Radiolysis (radionuclides in near-field water on near-field water composition)	1=Green
14.11 Dissolution/evaporation (radionuclides in near-field water on near-field gas)	2=Yellow
14.12 Decay heat (radionuclides in near-field water on near-field temperature)	1=Green
14.15 Source term (radionuclides in near-field water on radionuclides in far-field)	3=Red
15.9a Earth currents (far-field rock prop on near-field water comp.)	1=Green
15.9b Exchange (far-field water comp. on near-field water comp)	3=Red
15.10 Regional flow (far-field GW flow on near-field water flow)	3=Red
15.11a Gas flow (far-field gas on near-field gas)	1=Green
15.11b Composition (far-field gas on near-field gas)	1=Green
15.12 Heat exchange (far-field temp. on near-field temp.)	3=Red
15.13 Stress (far-field stress on near-field stress)	3=Red
15.14 Natural radionuclides (RN in far-field water on RN in near-field water)	1=Green

Appendix C: Far-field database



Contents

Group identification

The members of the group taking part in the construction of the matrix and the assignment of priorities to the interactions are given below.

SKB: T Eng, LO Ericsson, L Morén, O Olsson, A Ström, P Wikberg
Kemakta Konsult AB: K Skagius, M Wiborgh

Description of diagonal elements

1.1 Construction/layout

This element is introduced to take care of the influence of the construction work, the operation of the deep repository and the layout of the repository on the definition of the initial conditions of the repository system. Construction includes drilling, blasting, ventilation, grouting etc. The layout is according to the KBS-3 concept, i.e. a distributed tunnel system with canisters in deposition holes with a certain spacing. The definition includes access shafts and the existence of a surface facility for the deep repository.

2.2 Buffer/backfill/source

The properties of the backfill material in the tunnels of the repository and the source term for the radionuclide transport in the far-field is defined in this element. The source term is determined by the properties of the canisters with the spent fuel elements and the buffer around the canisters in the deposition holes. This element covers also the gas generated within the buffer. In addition, the heat generated by the waste and the temperature within the buffer and the backfill are included in the definition.

This element constitute boundary conditions for the far-field.

3.3 EDZ - Excavation Damaged Zone

The Excavation Damaged Zone is defined as the zone extending around an underground opening which is affected by the excavation process and subsequent mechanical processes. EDZ is defined as the part of the surrounding rock around the deposition holes as well as around the tunnels wherein the material properties are changed compared to the undisturbed rock. The hydraulic, mechanical and thermal properties of the EDZ are included in the definition.

4.4 Rock matrix/mineralogy

This element represents the intact rock and includes mineralogy as well as thermal and mechanical properties related to the mineralogy of the intact rock.

Comment: The starting point for endogenous scenarios are included, i e scenarios that deal with the forecast of movements driven by forces emanating from the earth's interior/crust.

5.5 Natural fracture system

The natural fracture system includes fracture mineralogy as well as thermal and mechanical properties of the natural fractures. Fracture zones of different magnitude are part of this definition. The fractures in the disturbed zone are included in the definition of the EDZ.

6.6 Groundwater chemistry

This element represents the groundwater chemistry in the EDZ and in the far-field rock. It includes the natural composition of:

- main constituents
- redox sensitive elements
- pH, Eh
- fulvic and humic acids
- bacteria
- colloids
- dissolved gases

which are affecting the performance of the barrier and radionuclide migration in the far field.

7.7 Groundwater movement

The fluid flow in the far-field rock, i e magnitude, direction and distribution of groundwater flow, is given by this element. Hydrogeological condition in terms of intrinsic permeability and effects of viscosity and density are considered. The groundwater movement in the tunnels, in the EDZ around tunnels and deposition holes, and the mixing of different waters are also covered by this element.

8.8 Groundwater pressure

The groundwater pressure here defined as the hydraulic head, f=ptot/rg+z. is the driving force for groundwater movement. In addition to hydraulic head this element also refers to the absolute pressure.

9.9 Temperature/heat

This element includes the temperature in the far-field as well as in the EDZ around tunnels and deposition holes.

10.10 Rock stresses

Rock stresses refer to the "total stresses" (effective stress+pore water pressure) which can be measured in-situ. In the definition the stresses in the far-field rock and in the EDZ around the tunnels and the deposition holes are included.

11.11 Gas generation and transport

Gas generation and gas transport in the rock matrix, in the natural fracture system, in the EDZ and in the backfilled tunnels are included in this element. Gas includes natural and waste generated gases of all kinds but not dissolved gases. Gas pressure is also included.

12.12 Transport of radionuclides

The transport of radionuclides in the far-field rock, in the EDZ around tunnels and deposition holes, and in the backfilled tunnels are included in the definition of this element.

13.13 Biosphere

All processes in the biosphere including vegetation, climate, wells, topography etc. This element constitutes boundary condition for the far field.

Comment: The starting point for exogenous scenarios that focus on predicting events and processes at the earth´s surface mainly caused by climatic conditions are included.

List of identified interactions with priorities

Element name and number	Priority
1.2 Excavation method	3=Red
1.3a Excavation method	3=Red
1.3b Grouting	1=Green
1.3c Reinforcement	1=Green
1.5 Displacement effects	2=Yellow
1.6a Construction materials	3=Red
1.6b Stray materials	3=Red
1.8 Drawdown effects	2=Yellow
1.9a Repository depth	3=Red
1.9b Ventilation	1=Green
1.10 Tunnel dimensions	3=Red
1.11a Ventilation	2=Yellow
1.11b Blasting gas	2=Yellow
1.11c Gas source	1=Green
1.13a Industrial facility	1=Green
1.13b Dumps	1=Green
2.1a Swelling ability	3=Red
2.1b Heat	3=Red
2.3 Buffer/backfill penetration into EDZ	2=Yellow
2.5 Buffer into intersecting fractures	2=Yellow
2.6a Colloid source	3=Red
2.6b Groundwater composition	3=Red
2.7a Changed flow around holes	2=Yellow
2.7b Changed flow in tunnels	3=Red
2.8 Resaturation	2=Yellow
2.9 Heat generation	3=Red
2.10 Swelling pressure	2=Yellow
2.11 Gas source	3=Red
2.12 Source term	3=Red
3.1a Excavation method	2=Yellow
3.1b Amount of reinforcement	2=Yellow
3.2a Volume for buffer/backfill swelling	2=Yellow
3.2b Rock fallout	2=Yellow
3.6a Changed porosity and surface area	1=Green
3.6b Colloid and particulate generation	2=Yellow
3.7 Changed permeability	3=Red
3.9 Modified thermal diffusivity	1=Green
3.10 Fractures affected	3=Red
3.11a Indiffusion of air	2=Yellow
3.11b Transport path for gas	2=Yellow
3.12a Changed porosity and surface area	3=Red
3.12b Sorption capacity	1=Green
4.1 Layout/construction method	2=Yellow
4.3 Magnitude and geometrical extent	2=Yellow
4.5 Fracture characteristics and infilling mineralisation	2=Yellow
4.6 Rock-water interaction	3=Red
4.7a Matrix conductivity	1=Green
4.7b Rock compressibility	1=Green
4.9 Thermal properties	3=Red
4.10 Genesis, tectonic history and rock type	2=Yellow
4.11 Radon generation	1=Green
4.12a Sorption	3=Red
4.12b Matrix diffusion	3=Red
4.13a Land use	2=Yellow
4.13b Potential human intrusion	2=Yellow
5.1a Avoid major fracture zones	3=Red
5.1b Constructability	2=Yellow
5.3 Mechanical properties and fracture frequency	2=Yellow
5.6a Dissolution of fracture minerals	2=Yellow

Element name and number	Priority
5.6b Colloid generation	3=Red
5.7a Flow paths	3=Red
5.7b Connectivity	3=Red
5.7c Fracture aperture	3=Red
5.7d Storage capacity	2=Yellow
5.9 Thermal properties	1=Green
5.10 Stress magnitude and orientation	1=Green
5.11 Transport path for gas	3=Red
5.12a Molecular diffusion	3=Red
5.12b Surface area	3=Red
5.12c Sorption	3=Red
5.13 Wells	3=Red
6.1a Depth affected by redox potential	3=Red
6.1b Construction materials	2=Yellow
6.2 TDS - ion exchange - illitisation	3=Red
6.3a Precipitation/bacterial growth operating phase	3=Red
6.3b Precipitation/bacterial growth in the long run	2=Yellow
6.4 Groundwater rock interaction	2=Yellow
6.5 Precipitation and dissolution of fracture minerals	2=Yellow
6.7 Density and viscosity	3=Red
6.8 Density affects groundwater head	3=Red
6.9 Heat conductivity	1=Green
6.11a Chemically generated gas	1=Green
6.11b Microbially generated gas	3=Red
6.11c Clathrates	2=Yellow
6.12a Sorption and solubility	3=Red
6.12b Colloids and bacteria	3=Red
6.13a Water use	2=Yellow
6.13b Biotopes	2=Yellow
7.1a Canister positioning	3=Red
7.1b Construction methods	2=Yellow
7.2a Saturation	2=Yellow
7.2b Bentonite erosion	2=Yellow
7.3 Erosion	1=Green
7.5 Erosion and sedimentation	1=Green
7.6 Mixing	3=Red
7.8 Equalisation of pressures	3=Red
7.9 Forced heat convection	2=Yellow
7.11 Two-phase flow	2=Yellow
7.12a Transport of dissolved gas	1=Green
7.12b Direction, distribution and magnitude	3=Red
7.12c Hydrodynamic dispersion	3=Red
7.13 Recharge and discharge	3=Red
8.1 Construction methods	2=Yellow
8.6 Solubility	1=Green
8.7 Driving force due to pressure gradient	3=Red
8.10 Effective stress	1=Green
8.11a Gas solubility	3=Red
8.11b Gas law	3=Red
8.13 Potential effect on vegetation	1=Green
9.2 Temperature in buffer/backfill	2=Yellow
9.4a Thermal expansion	1=Green
9.4b Thermal conductivity	1=Green
9.5 Permafrost	2=Yellow
9.6 Dissolution and precipitation of minerals	2=Yellow
9.7 Viscosity	3=Red
9.8 Density	3=Red
9.10 Thermal expansion	2=Yellow
9.11a Gas solubility	3=Red
9.11b Gas law	1=Green
9.12 Kinetic effects	1=Green

Element name and number	Priority
10.1a Design/layout	2=Yellow
10.1b Construction methods	2=Yellow
10.2a Reaction force on swelling pressure	2=Yellow
10.2b Rock fallout	2=Yellow
10.3a Mechanical stability	2=Yellow
10.3b Fracture aperture	3=Red
10.4 Mechanical stability	1=Green
10.5a Mechanical stability	2=Yellow
10.5b Fracture aperture	3=Red
10.8 Confined aquifers	1=Green
10.13 Mechanical stability	1=Green
11.1 Ventilation problems	2=Yellow
11.3a Opening of fractures	2=Yellow
11.3b Heat conduction	1=Green
11.4a Fracturing	2=Yellow
11.4b Thermal properties	1=Green
11.5 Fracture aperture	2=Yellow
11.6a pH and Eh affected	2=Yellow
11.6b Eh affected	3=Red
11.7 Creation of two-phase flow conditions	3=Red
11.8 Capillary forces	1=Green
11.9 Gas law	1=Green
11.12 Colloid sorption on gas bubbles	2=Yellow
11.13 Gas release	2=Yellow
12.1 Design/layout	3=Red
12.6a Radiolysis	1=Green
12.6b Redox front	3=Red
12.13 Contamination	3=Red
13.1 Siting - Design/Layout	3=Red
13.6 Infiltrating water	2=Yellow
13.7 Surface water recharge and percolation	3=Red
13.8a Land use	2=Yellow
13.8b Tidal driving forces	1=Green
13.8c Climatic driving forces	2=Yellow
13.8d Hydraulic gradients	3=Red
13.9 Climatic driving forces	2=Yellow
13.10a External load	2=Yellow
13.10b Erosion	2=Yellow

Appendix D: Process Report – List of Contents

SR 97 - Processes in Repository Evolution (1999, SKB Report TR 99-07, Svensk Kärnbränslehantering AB).

5 GEOSPHERE

Appendix E: Coupling between the SR 97 Process Report and the Interaction Matrices

Contents

Coupling between Process Report headings and the Interaction Matrices

Headings in the Process Report and coupling to the Interaction Matrices (B=Buffer, N=Near-field, F=Far-field). Interactions that are mapped to the initial state of the repository as well as FEPs that have not been described in the Process Report can be found in the following list. The diagonal elements and the interactions with priority =0 are not listed.

1 Introduction

1.1 References

2 Fuel/cavity in canister

2.1 Description of fuel/cavity

2.1.1 General

2.1.2 Overview of variables

2.1.3 Detailed description of fuel structure and radionuclide distribution in the structure

2.2 Overview of processes

2.3 Radiation-related processes

2.3.1 Radioactive decay

2.3.2 Radiation attenuation/heat generation
B 1.7 Fuel on nearfield temperature (by radioactive decay)
N 1.12 Decay heat (fuel on near-field temperature)

2.3.3 Induced fission (criticality)

2.4 Thermal processes

2.4.1 Heat transport
N 4.12 Heat transport (voids in canister on near-field temperature)
N 9.12 Heat transport (near-field water composition on near-field temperature)
N 11.12 Heat transport (near-field gas on near-field temperature)

2.5 Hydraulic processes

2.5.1 Water and gas transport in canister cavity, boiling/condensation
N 2.10 Integrity (steel canister on water flow through canister)
N 2.11b Gas release (steel canister on gas in canister)
N 3.10a Integrity (copper canister on water flow through canister)
N 3.11 Gas release (copper canister on gas inside canister)
N 4.10 Internal water pressure (voids in canister on near-field water flow)
N 5.10c Water exchange, canister (buffer on water flow through canister)
N 10.4 Intrusion/expulsion
N 11.10a Displacement (near-field gas on near-field water flow)
N 12.4 Phase changes (temperature in canister on voids in canister)

2.6 Mechanical processes

2.6.1 Thermal expansion/cladding failure
B 7.2c Temperature of canister on canister (by internal pressurizing)
N 12.11a Expansion/compression (near-field temperature on near-field gas)

2.7 Chemical processes

2.7.1 Advection and diffusion
N 10.9a Transport of species (near-field water flow on near-field water composition)
N 12.9d Diffusion (near-field temperature on near-field water composition)

2.7.2 Residual gas radiolysis/acid formation
N 1.11b Radiolysis (fuel on gas inside canister)

2.7.3 Water radiolysis
N 1.9b Radiolysis (fuel on water composition inside canister)
N 4.9b Extent of reactions (voids in canister on water composition in canister)
N 11.9b Radiolysis (gas in canister on water composition in canister)

2.7.4 Metal corrosion
N 1.4b Cladding corrosion (fuel on voids in canister)
N 1.9e Cladding corrosion (fuel on water composition in the canister)
N 1.11d Cladding corrosion (fuel on gas inside canister)
N 1.14c Cladding corrosion (fuel on water in canister)
N 4.1c Cladding corrosion (voids in canister on fuel)
N 4.9b Extent of reactions (voids in canister on water composition in canister)
N 9.1c Cladding corrosion (water composition in canister on fuel cladding)
N 11.1a Cladding corrosion (gas in canister on fuel)
N 12.1b Kinetics (temperature in canister on fuel)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.14a Kinetics (near-field temperature on radionuclides in near-field water)

2.7.5 Fuel dissolution
N 1.4a Dissolution/precipitation (fuel on voids in canister)
N 1.9c Oxidant sink (fuel on water composition in canister)
N 1.9b Radiolysis (fuel on water composition inside canister)
N 1.14a Dissolution/precipitation (fuel on radionuclides in water in canister)
N 4.1a Fuel alteration (voids in canister on fuel)
N 4.1b Fuel dissolution/precipitation (voids in canister on fuel)
N 4.9b Extent of reactions (voids in canister on water composition in canister)
N 4.14b Extent of reactions (voids in canister on radionuclides in water in canister)
N 9.1a Fuel alteration (water composition in canister on fuel matrix)
N 9.1b Fuel dissolution/precipitation (water composition in canister on fuel)
N 12.1b Kinetics (temperature in canister on fuel)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
N 12.14a Kinetics (near-field temperature on radionuclides in near-field water)
N 14.9b Redox front (radionuclides in near-field water on near-field water comp.)

2.7.6 Dissolution of gap inventory
N 1.14b Instant release (fuel on radionuclides in water in canister)
N 4.14c Volume effect on IRF (voids in canister on radionuclides in water in canister)

2.7.7 Speciation of iron corrosion products
F 12.6b Redox front
N 2.9 Corrosion (steel canister on water composition in canister)
N 4.2c Solubility (voids in canister on steel canister)
N 4.9a Solubility (voids in canister on water composition in canister)
N 12.1c Equilibria (near-field temperature on fuel)
N 12.2d Equlibria (temperature in canister on steel canister)
N 12.9b Equilibria (near-field temperature on near-field water composition)

2.7.8 Speciation of radionuclides, colloid formation
N 1.9d Fuel dissolution (fuel on water composition in canister)
N 1.14a Dissolution/precipitation (fuel on radionuclides in water in canister)
N 1.14b Instant release (fuel on radionuclides in water in canister)
N 4.1d Solubility (voids in canister on fuel)
N 4.9a Solubility (voids in canister on water composition in canister)
N 4.14a Solubility (voids in canister on radionuclides in water in canister)
N 9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)
N 12.1c Equilibria (near-field temperature on fuel)
N 12.9b Equilibria (near-field temperature on near-field water composition)
N 12.14b Equilibria (near-field temperature on radionuclides in near-field water)
N 14.1 Dissolution/precipitation (radionuclides in water in canister on fuel)

2.7.9 Helium production
N 1.11a Helium production (fuel on gas inside canister)

2.8 Radionuclide transport
N 1.11e Radioactive gas (fuel on radioactive gas in canister)
N 2.14a Sorption/desorption (steel canister on radionuclides in water in canister)
N 2.14b Diffusion (steel canister on radionuclides in near-field water)
N 2.14c Colloid filter (steel canister on radionuclides in near-field water)
N 3.14a Sorption/desorption (copper canister on radionuclides in the water in the canister)
N 3.14b Diffusion (copper canister on radionuclides in near-field water)
N 3.14c Colloid filter (copper canister on radionuclides in near-field water)
N 4.14b Extent of reactions (voids in canister on radionuclides in water in canister)
N 9.14b Sorption/desorption (near-field water comp. on radionucl. in near-field water)
N 9.14c Colloid transport (near-field water comp. on radionucl. in near-field water)
N 10.14a Transport of dissolved RN (n-f water flow on radionucl. in near-field water)
N 12.14c Diffusion (near-field temperature on radionuclides in near-field water)
N 14.2 Contamination (radionuclides in water in canister on steel canister)
N 14.3 Contamination (radionuclides in near-field water on copper canister)

2.9 References

3 Cast iron insert/copper canister

3.1 Description of cast iron insert and copper canister

3.1.1 General

3.1.2 Overview of variables

3.2 Overview of processes

3.3 Radiation-related processes

3.3.1 Radiation attenuation/heat generation

3.4 Thermal processes

3.4.1 Heat transport
B 2.7 Canister on nearfield temperature (by transfer of heat from fuel)
N 2.12 Heat transport (steel canister on temperature in near-field)
N 3.12 Heat transport (copper canister on near-field temperature)

3.5 Hydraulic processes

3.6 Mechanical processes

3.6.1 Introduction

3.6.2 Deformation of cast iron insert
N 11.2d Internal impact (gas in canister on steel canister)
N 11.3b Internal impact (gas in canister on copper canister)

3.6.3 Deformation of copper canister from external pressure

B 3.2b Buffer on canister (by affecting its shape through swelling pressure)
B 4.2b Buffer porewater on canister (by pressurizing canister)
N 3.4 Void size (copper canister on voids in canister)
N 4.3 Mechanical stability (voids in canister on copper canister)
N 5.3b Swelling pressure (buffer on copper canister)
N 5.3e Porewater pressure (hydrostatic pressure) (buffer on copper canister)

3.6.4 Thermal expansion (both cast iron insert and copper canister)

B 7.2a Temperature of canister on canister (by changing its size and shape)
B 7.2b Temperature of canister on canister (by affecting its material structure)
N 2.4b Void size (steel canister on voids in canister)
N 3.4 Void size (copper canister on voids in canister)
N 12.2a Expansion/contraction (temperature in canister on steel canister)
N 12.2b Mechanical strength (temperature in canister on steel canister)
N 12.3a Expansion/contraction (temperature in canister on copper canister)
N 12.3b Mechanical strength (temperature in canister on copper canister)

3.6.5 Deformation from internal corrosion products

N 2.3 Yawning (steel canister on copper canister)
N 2.4a Corrosion products (steel canister on voids in canister)

3.7 Chemical processes

3.7.1 Corrosion of cast iron insert

B 2.4 Canister on buffer porewater (by ion release)
B 2.6 Canister on nearfield gas (by corrosion)
N 2.4a Corrosion products (steel canister on voids in canister)
N 2.9 Corrosion (steel canister on water composition in canister)
N 2.11a Corrosion gas (steel canister on gas in canister)
N 4.2a External corrosion (voids in canister on steel canister)
N 4.2b Internal corrosion (voids in canister on steel canister)
N 9.2 Corrosion (water composition in canister on steel canister)
N 11.2b Corrosion by water vapour (gas in canister on steel canister)
N 11.2c Hydrogen pressure (gas in canister on steel canister)
N 12.2c Kinetics (temperature in canister on steel canister)
N 12.9a Kinetics (near-field temperature on near-field water composition)

3.7.2 Galvanic corrosion

B 2.4 Canister on buffer porewater (by ion release)
N 3.2b Galvanic corrosion (copper canister on steel canister)

3.7.3 Stress corrosion cracking of cast iron insert

B 2.4 Canister on buffer porewater (by ion release)
B 6.2b Buffer gas on canister (by corrosion)
N 11.2a Corrosion by nitrous gases (gas in canister on steel canister)

3.7.4 Radiation effects

B 1.2 Fuel on canister (by radiation)
N 1.2a Radiation (fuel on steel canister)
N 1.2b Neutron activation (fuel on steel canister)
N 1.3a Radiation (fuel on copper canister)

3.7.5 Corrosion of copper canister
B 1.6 Fuel on nearfield gas (by radiation)
B 2.4 Canister on buffer porewater (by ion release)
B 4.2a Buffer porewater on canister (by corrosion)
B 6.2b Buffer gas on canister (by corrosion)
N 1.11c Radiolysis (fuel on gas outside canister)
N 3.9 Corrosion (copper canister on water composition in buffer and in canister)
N 9.3 Corrosion (composition of buffer porewater on copper canister)
N 11.3a Corrosion (near-field gas on copper canister)
N 12.3c Kinetics (temperature in canister on copper canister)
N 12.3d Equlibria (temperature in canister on copper canister)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)

3.7.6 Stress corrosion cracking, copper canister
B 2.4 Canister on buffer porewater (by ion release)
B 6.2b Buffer gas on canister (by corrosion)
N 5.3d SCC (buffer on copper canister)
N 11.3a Corrosion (near-field gas on copper canister)

3.8 Radionuclide transport

3.9 References

4 Buffer/backfill

4.1 Description of buffer and backfill

4.1.1 General

4.1.2 Overview of variables

4.2 Overview of processes

4.3 Radiation-related processes

4.3.1 Radiation attenuation/heat generation

4.4 Thermal processes

4.4.1 Heat transport

B 3.7a Buffer on buffer temperature (by heat flow)
B 4.7a Buffer porewater on buffer temperature (by heat conductivity)
B 5.7 Buffer non-smect. min./ impurities on buffer/canister temperature (by affect. heat conductivity)
B 6.7 Buffer gas on buffer/canister temperature (by thermal isolation)
B 7.3b Temperature of buffer on buffer (by affecting its thermal properties)
B 8.7 Groundwater hydrology on nearfield temperature (by heat transport through convection)
B 9.7 Groundwater chemistry on nearfield temp. (by affecting the heat conductivity of nearfield water)
B 12.7 Backfill on nearfield temperature (by heat flow)
N 5.12 Heat transport (buffer on temperature in canister and buffer)
N 6.12 Heat transport (backfill on near-field temperature)
N 9.12 Heat transport (near-field water composition on near-field temperature)
N 10.12 Heat convection (near-field water flow on near-field temperature)
N 11.12 Heat transport (near-field gas on near-field temperature)
N 12.5g Thermal properties (tmperature in buffer on buffer)
F 2.9 Heat generation
F 9.2 Temperature in buffer/backfill

4.5 Hydraulic processes

4.5.1 Water transport under unsaturated conditions

B 3.4h Buffer on buffer porewater (by affecting the pressure state)
B 4.12 Buffer porewater on backfill (by affecting its porewater pressure)
B 4.6a Buffer porewater on buffer gas (by vapor pressure)
B 4.6c Buffer porewater on buffer gas (by affecting the mobility of gas)
B 4.8 Buffer porewater on groundwater hydrology (by exerting pressure)
B 6.12a Gas in backfill on backfill (by affecting the degree of water saturation)
B 7.4a Temperature of buffer on buffer porewater (by redistribution)
B 7.6a Temperature of buffer on buffer gas (by affecting its pressure)
B 7.6b Temperature on buffer gas (by vapor transport)
B 8.12b Groundwater hydrology on backfill (by providing water for saturation)
B 8.3b Groundwater hydrology on buffer (by providing water for saturation)
B 8.3c Groundwater hydrology on buffer (by affecting pressure heads and hence conditions for saturat.)
B 12.6b Backfill on nearfield gas (by storing gas)
B 12.8 Backfill on groundwater hydrology (by distribution of flow in and through the backfill)
N 5.10b Flow in buffer (buffer on water flow in buffer)
N 5.10c Water exchange, canister (buffer on water flow through canister)
N 11.6a Dehydration (gas in backfill on backfill)
N 12.10a Convection cells (near-field temperature on near-field water flow)
N 12.11b Gas dissolution (near-field temperature on near-field gas)
F 7.2a Saturation

4.5.2 Water transport under saturated conditions

B 7.3a Temperature of buffer on buffer (by affecting the hydraulic conductivity)
B 7.4b Temperature of buffer on buffer porewater (by affecting the viscosity)
B 7.12c Temperature of nearfield on backfill (by affecting its hydraulic conductivity)
B 9.8a Groundwater chemistry on groundwater hydrology (by buoyancy effects)
B 12.8 Backfill on groundwater hydrology (by distribution of flow in and through the backfill)
N 5.10b Flow in buffer (buffer on water flow in buffer)
N 5.10c Water exchange, canister (buffer on water flow through canister)
N 6.10 Local hydrology (backfill on near-field water flow)
N 9.10 Density, viscosity (near-field water composition on near-field water flow)
N 10.5a Pressure (near-field water flow on buffer)
N 12.5c Hydraulic conductivity (temperature in buffer on buffer)
N 12.6c Hydraulic conductivity (temperature in buffer on buffer)
N 12.10a Convection cells (near-field temperature on near-field water flow)
N 12.10b Viscosity (near-field temperature on near-field water flow)
F 2.7b Changed flow in tunnels

4.5.3 Gas transport/dissolution

B 2.6 Canister on nearfield gas (by corrosion)
B 3.6b Buffer on buffer gas pressure (by release of gas)
B 3.6c Buffer on buffer gas (by gas conductivity)
B 4.6b Buffer porewater on buffer gas (by dissolution of gas in porewater)
B 4.6d Buffer porewater on buffer gas (by affecting the pressure for release of gas)
B 6.3a Buffer gas on buffer (by piping)
B 6.3b Buffer gas on buffer (by affecting its homogeneity, i.a. through forming flow paths)
B 6.3c Buffer gas on buffer (by affecting the hydration state)
B 6.4a Buffer gas on buffer porewater (by being dissolved)
B 6.12b Gas in backfill on backfill (by causing piping and erosion)
B 7.6c Temperature of buffer on buffer gas (by affecting gas solubility)
B 8.6a Groundwater hydrology on nearfield gas (by aff. water pressure in the nearf. rock and backfill)
B 8.6b Groundwater hydrology on nearfield gas (by affect. gas migration in nearfield rock and backfill)
B 9.6 Groundwater chemistry on nearfield gas (by affecting its solubility)
B 12.6a Backfill on nearfield gas (by affecting its pressure)
B 12.6b Backfill on nearfield gas (by storing gas)
N 5.9g Solubility (buffer on composition of buffer porewater)
N 5.11 Gas flow in buffer (buffer properties on gas in buffer)
N 6.11 Gas flow (backfill on near-field gas)
N 9.11a Gas dissolution (near-field water composition on near-field gas)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 10.11a Pressure (near-field water flow on near-field gas)
N 10.11b Gas dissolution (near-field water flow on near-field gas)
N 10.11c Two-phase flow (near-field water flow on near-field gas)
N 11.5a Piping (gas in buffer on buffer)
N 11.5b Flotation (gas in buffer on buffer)
N 11.5d Dehydration (gas inside buffer on buffer)
N 11.6b Piping (gas in backfill on backfill)
N 11.9a Gas dissolution (near-field gas on near-field water composition)
N 11.10a Displacement (near-field gas on near-field water flow)
N 12.11b Gas dissolution (near-field temperature on near-field gas)
F 2.11 Gas source

4.6 Mechanical processes

4.6.1 Swelling

B 3.4b Buffer on buffer porewater (by affecting its physical state)
B 3.10c Buffer on nearfield rock (by self-sealing)
B 4.3a Buffer porewater on buffer (by producing swelling pressure and expandability)
B 4.3f Buffer porewater on buffer (by affecting the microstructural homogeneity)
B 10.3a Nearfield rock on buffer (by affecting confining function)
B 10.3c Nearfield rock on buffer (by reducing its density through loss of buffer into fractures)
N 5.7 Intrusion (buffer on near-field rock)
N 5.9f Water activcity (buffer on buffer porewater)
N 7.5b Confinement (near-field rock on buffer)
N 7.5c Density decrease (near-field rock on buffer)
N 9.5c Microstructural constitution (composition of buffer porewater on buffer)
N 9.6c Swelling (composition of backfill water on backfill)
F 2.3 Buffer/backfill penetration into EDZ
F 2.5 Buffer into intersecting fractures
F 10.2a Reaction force on swelling pressure

4.6.2 Mechanical interaction buffer/backfill

B 3.12 Buffer on backfill (by swelling pressure)
B 12.3 Backfill on buffer (by providing confinement)
N 5.6 Swelling pressure (buffer on backfill)
N 6.5 Confinement (backfill on buffer)

4.6.3 Mechanical interaction buffer/canister

B 2.3a Canister on buffer (by affecting the density through pressurizing)
B 3.2a Buffer on canister (by affecting its position through swelling pressure anomalies)
B 3.2b Buffer on canister (by affecting its shape through swelling pressure)
B 3.2c Buffer on canister (by affecting position and shape through shearing)
B 4.2b Buffer porewater on canister (by pressurizing canister)
B 6.2a Buffer gas on canister (by pressurization)
N 3.5a Density (canister on buffer)
N 3.5b Expansion/compression (copper canister on buffer)
N 4.5 Buffer intrusion (steel canister on buffer)
N 5.3a Confinement (buffer on copper canister)
N 5.3b Swelling pressure (buffer on copper canister)
N 5.3c Shear (buffer on copper canister)
N 5.3e Porewater pressure (hydrostatic pressure) (buffer on copper canister)
N 5.4 Buffer intrusion (buffer on voids in canister)
N 11.2e External impact (gas outside steel canister on steel canister)

4.6.4 Mechanical interaction buffer/near-field rock

B 3.10a Buffer on nearfield rock (by affecting the stability through swelling pressure)
B 3.10b Buffer on nearfield rock (by affecting frac- ture aperture through swelling pressure)
B 3.10c Buffer on nearfield rock (by self-sealing)
B 10.3a Nearfield rock on buffer (by affecting confining function)
B 10.3b Nearfield rock on buffer (by imposing shear strain)
B 10.3e Nearfield rock on buffer (by aff. its density through time-dep. convergence of the dep. holes)
N 5.13a Swelling pressure (buffer on near-field rock stresses)
N 7.5a Rock displacement (near-field rock on buffer)
N 7.5b Confinement (near-field rock on buffer)
N 13.5a Rock displacement (near-field rock stresses on buffer)
N 13.5b Rock creep (near-field rock stresses on buffer)
F 2.10 Swelling pressure
F 3.2b Rock fallout
F 10.2a Reaction force on swelling pressure
F 10.2b Rock fallout

4.6.5 Mechanical interaction backfill/near-field rock

B 10.12a Nearfield rock on backfill (by providing confinement)
B 12.10a Backfill on nearfield rock (by affecting its structure through pressurizing)
B 12.10b Backfill on nearfield rock (by affecting its stability through pressurizing)
N 6.13a Swelling pressure (backfill on near-field rock stresses)
N 7.6a Rock movements (near-field rock on backfill)
N 7.6b Confinement (near-field rock on backfill)
N 13.6a Rock displacement (near-field rock stresses on backfill)
N 13.6b Rock creep (near-field rock stresses on backfill)
F 1.2 Excavation method
F 2.10 Swelling pressure
F 3.2b Rock fallout
F 10.2a Reaction force on swelling pressure
F 10.2b Rock fallout

4.6.6 Thermal expansion

B 4.8 Buffer porewater on groundwater hydrology (by exerting pressure)
B 4.10 Buffer porewater on nearfield rock (by exerting pressure on the rock)
B 4.12 Buffer porewater on backfill (by affecting its porewater pressure)
B 7.3c Temperature of buffer on buffer (by affecting its swelling pressure)
B 7.3d Buffer temperature on buffer (by affecting its total pressure)
B 7.3e Temperature of buffer on buffer (by affecting its shear strength)
B 7.4f Temperature of buffer on buffer porewater (by affecting its pressure)
N 5.13b Porewater pressure (buffer on near-field rock stresses)
N 12.5d Swelling pressure (temperature in buffer on buffer)
N 12.5e Expansion/contraction (temperature in buffer on buffer)
N 12.5f Porewater pressure (temperature in buffer on buffer)
N 12.5h Shear strength (temperature in buffer on buffer)

4.7 Chemical processes

4.7.1 Introduction, cementation

4.7.2 Advection

B 3.4g Buffer on buffer porewater (by flow)
B 8.4 Groundwater hydrology on buffer porewater (by affecting its chemical composition)
B 8.9a Groundwater hydrology on groundwater chemistry (by introducing water with diff. composition)
B 8.9b Groundwater hydrology on groundwater chemistry (by mixing and dilution)
B 9.4 Groundwater chemistry on buffer porewater (by affecting its chemical composition)
N 10.9a Transport of species (near-field water flow on near-field water composition)

4.7.3 Diffusion

B 3.4a Buffer on buffer porewater (by ion diffusion)
B 9.4 Groundwater chemistry on buffer porewater (by affecting its chemical composition)
N 5.9d Diffusion (buffer on near-field water composition)
N 6.9d Diffusion (backfill on near-field water composition)
N 12.9d Diffusion (near-field temperature on near-field water composition)

4.7.4 Ion exchange/sorption

B 3.4b Buffer on buffer porewater (by affecting its physical state)
B 3.4d Buffer on buffer porewater (by ion exchange)
B 3.4f Buffer on buffer porewater (by sorption)
B 4.3d Buffer porewater on buffer smectite (by ion-exchange)
B 4.3f Buffer porewater on buffer (by affecting the microstructural homogeneity)
B 7.4c Temperature of buffer on buffer porewater (by affecting the rate of chemical reactions)
B 9.12b Groundwater chemistry on backfill (by sorption)
B 12.9b Backfill on groundwater chemistry (by sorption)
N 5.9c Ion-exchange/sorption (buffer on near-field water composition)
N 5.9f Water activcity (buffer on buffer porewater)
N 6.9c Ion-exchange/sorption (backfill on backfill water composition)
N 9.5a Ion-exchange/sorption (composition of buffer porewater on buffer)
N 9.5c Microstructural constitution (composition of buffer porewater on buffer)
N 9.6a Ion exchange/sorption (composition of backfill water on backfill)
N 9.6c Swelling (composition of backfill water on backfill)
F 6.2 TDS - ion exchange - illitisation

4.7.5 Montmorillonite transformation

B 3.4c Buffer on buffer porewater (by dissolution of smectite)
B 4.3b Buffer porewater on buffer (by dissolution of the smectite content)
B 4.3c Buffer porewater on buffer smectite (by formation of smectite)
B 4.3e Buffer porewater on buffer smectite (by degrading and alterating it)
B 7.3f Temperature of buffer on buffer smectite (by affecting chemical equilibria)
B 7.3g Temperature of buffer on buffer (by affecting the rate of alteration of the smectite)
B 7.4c Temperature of buffer on buffer porewater (by affecting the rate of chemical reactions)
B 7.4d Temperature of buffer on buffer porewater (by determining the state of chemical equilibrium)
B 7.12a Temperature of nearfield on backfill (by affecting chemical equilibria)
B 7.12b Temperature of nearfield on backfill (by affecting the rate of chemical changes)
B 9.12a Groundwater chemistry on backfill (by affecting chemical equilibria)
B 12.9a Backfill on groundwater chemistry (by diss. of minerals and affecting chemical equilibria)
N 5.9b Dissolution/precipitation (buffer on water composition in near-field)
N 5.9g Solubility (buffer on composition of buffer porewater)
N 6.9b Dissolution/precipitation (backfill on near-field water composition)
N 9.5b Dissolution/precipitation (composition of buffer porewater on buffer)
N 9.5d Illitization (composition of buffer porewater on buffer)
N 9.6b Dissolution/precipitation (composition of backfill water on backfill)
N 10.6b Solubility (near-field water flow on backfill)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 12.5a Kinetics (temperature in buffer on buffer)
N 12.5b Equlibria (temperature in buffer on buffer)
N 12.6a Kinetics (temperature in backfill on backfill)
N 12.6b Equilibria (temperature in backfill on backfill)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
F 6.2 TDS - ion exchange - illitisation

4.7.6 Dissolution/precipitation of impurities

B 3.4c Buffer on buffer porewater (by dissolution of smectite)
B 4.5a Buffer porewater on buffer non-smectite minerals/ impurities (by dissolution)
B 4.5b Buffer porewater on buffer non-smectite minerals/impurities (by precipitation)
B 5.4a Buffer non-smectite minerals/impurities on buffer porewater (by being dissolved)
B 5.4b Buffer non-smectite minerals/impurities on buffer porewater (by being precipitated)
B 5.4c Buffer non/smectite minerals/impurities on buffer porewater (by forming colloids)
B 7.4c Temperature of buffer on buffer porewater (by affecting the rate of chemical reactions)
B 7.4d Temperature of buffer on buffer porewater (by determining the state of chemical equilibrium)
B 7.5a Temperature of buffer on buffer non-smectite minerals/impurities (by affect. chemical equilibria)
B 7.5b Temperature of buffer on buffer non-smectite miner./impurities (by affecting the rate of change)
B 7.12a Temperature of nearfield on backfill (by affecting chemical equilibria)
B 7.12b Temperature of nearfield on backfill (by affecting the rate of chemical changes)
B 9.12a Groundwater chemistry on backfill (by affecting chemical equilibria)
B 12.9a Backfill on groundwater chemistry (by diss. of minerals and affecting chemical equilibria)
N 5.9b Dissolution/precipitation (buffer on water composition in near-field)
N 5.9g Solubility (buffer on composition of buffer porewater)
N 6.9b Dissolution/precipitation (backfill on near-field water composition)
N 9.5b Dissolution/precipitation (composition of buffer porewater on buffer)
N 9.6b Dissolution/precipitation (composition of backfill water on backfill)
N 10.6b Solubility (near-field water flow on backfill)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 12.5a Kinetics (temperature in buffer on buffer)
N 12.5b Equlibria (temperature in buffer on buffer)
N 12.6a Kinetics (temperature in backfill on backfill)
N 12.6b Equilibria (temperature in backfill on backfill)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
F 6.2 TDS - ion exchange - illitisation

4.7.7 Colloid release/erosion

B 3.4e Buffer on buffer porewater (by producing colloids)
B 3.10c Buffer on nearfield rock (by self-sealing)
B 8.3a Groundwater hydrology on buffer smectite (by eroding smectite that has entered fractures)
B 8.5 Groundwater hydrology on buffer non-smectite minerals/impurities (by erosion of buffer)
B 8.12a Groundwater hydrology on backfill (by piping and erosion)
B 10.3c Nearfield rock on buffer (by reducing its density through loss of buffer into fractures)
B 10.12b Nearfield rock on backfill (by reduction of density through loss of backfill into fractures)
B 12.10c Backfill on nearfield rock (by penetrating into and sealing fractures)
N 5.7 Intrusion (buffer on near-field rock)
N 5.9a Colloid source (buffer on water composition in near-field rock)
N 6.9a Colloid source (backfill on near-field water composition)
N 7.5c Density decrease (near-field rock on buffer)
N 7.6c Density decrease (near-field rock on backfill)
N 10.5b Erosion (near-field water flow on buffer)
N 10.6a Erosion (near-field water flow on backfill)
F 2.3 Buffer/backfill penetration into EDZ
F 2.5 Buffer into intersecting fractures
F 2.6a Colloid source
F 3.2a Volume for buffer/backfill swelling
F 7.2b Bentonite erosion

4.7.8 Radiation-induced montmorillonite transformation
B 1.3 Fuel on buffer smectite (by radiation)
B 1.12 Fuel on backfill (by radiation)
N 1.5 Radiation (fuel on buffer)
N 1.6 Radiation (fuel on backfill)
N 14.5b Radiation effects (radionuclides in buffer porewater on buffer)
N 14.6b Radiation effects (radionuclides in backfill water on backfill)

4.7.9 Radiolysis of pore water
B 1.4 Fuel on buffer porewater (by radiolysis)
B 1.9 Fuel on groundwater chemistry in nearfield
N 1.9a Radiolysis (fuel on water composition outside the canister)

4.7.10 Microbial processes
B 3.4b Buffer on buffer porewater (by affecting its physical state)
B 4.6e Buffer porewater on buffer gas (by microbial activity)
N 5.9f Water activcity (buffer on buffer porewater)
N 9.11b Microbial activity (near-field water composition on near-field gas)

4.8 Radionuclide transport

4.8.1 Overview

4.8.2 Advection
N 10.14a Transport of dissolved RN (n-f water flow on radionucl. in near-field water)

4.8.3 Colloid transport
N 5.9e Colloid filter (buffer on porewater composition)
N 5.14c Colloid filter (buffer on radionuclides in near-field water outside the buffer)
N 6.14c Colloid filter (backfill on radionuclides in near-field water)
N 9.14c Colloid transport (near-field water comp. on radionucl. in near-field water)

4.8.4 Speciation of radionuclides
N 5.14d Solubility (buffer on radionuclides in buffer porewater)
N 9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)
N 12.14b Equilibria (near-field temperature on radionuclides in near-field water)

4.8.5 Sorption
N 5.14a Ion-exchange, sorption (buffer on radionuclides in buffer porewater)
N 6.14a Ion-exchange, sorption (backfill on radionuclides in near-field water)
N 9.14b Sorption/desorption (near-field water comp. on radionucl. in near-field water)
N 12.14a Kinetics (near-field temperature on radionuclides in near-field water)
N 14.5a Contamination (radionuclides in buffer porewater on buffer)
N 14.6a Contamination (radionuclides in backfill water on backfill)

4.8.6 Diffusion
N 5.14b Diffusion (buffer on radionuclides in near-field water)
N 6.14b Diffusion (backfill on radionuclides in near-field water)
N 12.14c Diffusion (near-field temperature on radionuclides in near-field water)

4.8.7 Decay

5 Geosphere

5.1 Description of the geosphere

5.1.1 General

5.1.2 Overview of variables

5.2 Overview of processes

5.3 Radiation-related processes

5.4 Thermal processes

5.4.1 Heat transport

B 8.7 Groundwater hydrology on nearfield temperature (by heat transport through convection)
B 9.7 Groundwater chemistry on nearfield temp. (by affecting the heat conductivity of nearfield water)
B 10.7 Nearfield rock on nearfield temperature (by aff. heat transport through its thermal conductivity)
N 7.12 Heat transport (near-field rock on near-field temperature)
N 9.12 Heat transport (near-field water composition on near-field temperature)
N 10.12 Heat convection (near-field water flow on near-field temperature)
N 11.12 Heat transport (near-field gas on near-field temperature)
N 12.15 Heat transfer (near-field temperature on far-field temperature)
N 12.7e Thermal conductivity (temperature in near-field rock on near-field rock)
N 15.12 Heat exchange (far-field temp. on near-field temp.)
F 3.9 Modified thermal diffusivity
F 4.9 Thermal properties
F 5.9 Thermal properties
F 7.9 Forced heat convection
F 9.2 Temperature in buffer/backfill
F 9.4b Thermal conductivity
F 11.3b Heat conduction
F 11.4b Thermal properties
F 13.9 Climatic driving forces

5.5 Hydraulic processes

5.5.1 Groundwater flow

B 7.8a Temperature of nearfield on groundwater hydrology (by groundwater convection)
B 7.8b Temperature of nearfield on groundwater hydrology (by affecting the viscosity)
B 9.8a Groundwater chemistry on groundwater hydrology (by buoyancy effects)
B 9.8b Groundwater chemistry on groundwater hydrology (by affecting water viscosity)
B 10.8 Nearfield rock on groundwater hydrology (by its structural constitution)
N 7.10 Local hydrology (near-field rock on near-field water flow)
N 9.10 Density, viscosity (near-field water composition on near-field water flow)
N 10.15 Hydraulic gradient (near-field water flow on far-field water flow)
N 12.10a Convection cells (near-field temperature on near-field water flow)
N 12.10b Viscosity (near-field temperature on near-field water flow)
N 15.10 Regional flow (far-field GW flow on near-field water flow)
F 2.8 Resaturation
F 3.7 Changed permeability
F 4.7a Matrix conductivity
F 5.7a Flow paths
F 5.7b Connectivity
F 5.7c Fracture aperture
F 5.7d Storage capacity
F 5.13 Wells
F 6.7 Density and viscosity
F 6.8 Density affects groundwater head
F 7.8 Equalisation of pressures
F 7.11 Two-phase flow
F 7.13 Recharge and discharge
F 8.7 Driving force due to pressure gradient
F 9.5 Permafrost
F 9.7 Viscosity
F 9.8 Density
F 11.7 Creation of two-phase flow conditions
F 11.8 Capillary forces
F 13.7 Surface water recharge and percolation
F 13.8a Land use
F 13.8c Climatic driving forces
F 13.8d Hydraulic gradients

5.5.2 Gas flow/dissolution

B 6.8 Gas in nearfield rock on groundwater hydrology (by affecting the flow paths)
B 6.10a Gas in nearfield rock on nearfield rock (by affecting the degree of water saturation)
B 8.6a Groundwater hydrology on nearfield gas (by aff. water pressure in the nearf. rock and backfill)
B 8.6b Groundwater hydrology on nearfield gas (by affect. gas migration in nearfield rock and backfill)
B 10.6a Nearfield rock on nearfield gas (by controlling the release of gas)
B 10.6b Nearfield rock on nearfield gas (by storing gas)
B 12.6b Backfill on nearfield gas (by storing gas)
N 7.11 Gas flow (near-field rock on near-field gas)
N 10.11a Pressure (near-field water flow on near-field gas)
N 10.11b Gas dissolution (near-field water flow on near-field gas)
N 10.11c Two-phase flow (near-field water flow on near-field gas)
N 10.14b Transport of dissolved gas (n-f water flow on radionucl. in near-field water)
N 11.7a Dehydration (gas in near-field rock on near-field rock)
N 11.7c Fractures (gas in near-field rock on near-field rock)
N 11.10b Two-phase flow (near-field gas on near-field water flow)
N 11.15a Gas flow (near-field gas on far-field gas)
N 11.15b Composition (near-field gas on far-field gas)
N 12.11b Gas dissolution (near-field temperature on near-field gas)
N 15.11a Gas flow (far-field gas on near-field gas)
F 3.11b Transport path for gas
F 5.11 Transport path for gas
F 7.11 Two-phase flow
F 8.11b Gas law
F 9.11b Gas law
F 11.3a Opening of fractures
F 11.4a Fracturing
F 11.5 Fracture aperture
F 11.7 Creation of two-phase flow conditions
F 11.8 Capillary forces

5.6 Mechanical processes

5.6.1 Introduction

5.6.2 Movements in intact rock

N 15.13 Stress (far-field stress on near-field stress)
F 4.7b Rock compressibility

5.6.3 Thermal movement

B 7.10a Temperature of nearfield on nearfield rock (by affecting the structure)
B 7.10b Temperature of nearfield on nearfield rock (by affecting the mechanical stability)
N 7.13 Stress relaxation (near-field rock on near-field rock stresses)
N 12.7a Fracturing (temperature in near-field rock on near-field rock)
N 12.7b Fracture aperture (temperature in near-field rock on near-field rock)
F 9.4a Thermal expansion
F 9.10 Thermal expansion

5.6.4 Reactivation-movement along existing fractures

B 3.10a Buffer on nearfield rock (by affecting the stability through swelling pressure)
B 3.10b Buffer on nearfield rock (by affecting frac- ture aperture through swelling pressure)
B 7.10a Temperature of nearfield on nearfield rock (by affecting the structure)
B 7.10b Temperature of nearfield on nearfield rock (by affecting the mechanical stability)
B 10.3b Nearfield rock on buffer (by imposing shear strain)
N 7.5a Rock displacement (near-field rock on buffer)
N 10.13 Effective stress (near-field water flow on near-field rock stresses)
N 12.7b Fracture aperture (temperature in near-field rock on near-field rock)
N 13.5a Rock displacement (near-field rock stresses on buffer)
N 13.6a Rock displacement (near-field rock stresses on backfill)
N 13.7b Fracture aperture (near-field rock stresses on near-field rock)
N 15.13 Stress (far-field stress on near-field stress)
F 3.10 Fractures affected
F 8.10 Effective stress
F 10.3a Mechanical stability
F 10.3b Fracture aperture
F 10.5a Mechanical stability
F 10.5b Fracture aperture
F 13.10a External load

5.6.5 Fracturing

B 7.10b Temperature of nearfield on nearfield rock (by affecting the mechanical stability)
N 7.5a Rock displacement (near-field rock on buffer)
N 12.7a Fracturing (temperature in near-field rock on near-field rock)
N 13.7a Fracturing (near-field rock stresses on near-field rock)
N 15.13 Stress (far-field stress on near-field stress)
F 3.10 Fractures affected
F 10.3a Mechanical stability
F 10.3b Fracture aperture
F 10.4 Mechanical stability
F 10.5a Mechanical stability
F 10.5b Fracture aperture
F 13.10a External load

5.6.6 Time-dependent deformations

B 10.3e Nearfield rock on buffer (by aff. its density through time-dep. convergence of the dep. holes)
N 13.5b Rock creep (near-field rock stresses on buffer)
N 13.6b Rock creep (near-field rock stresses on backfill)
N 13.7a Fracturing (near-field rock stresses on near-field rock)
N 13.7b Fracture aperture (near-field rock stresses on near-field rock)
N 15.13 Stress (far-field stress on near-field stress)
F 10.2b Rock fallout
F 10.3a Mechanical stability
F 10.3b Fracture aperture

5.7 Chemical processes

5.7.1 Introduction

5.7.2 Advection/mixing

B 4.9 Buffer porewater on groundwater chemistry (by supplying or extracting dissolved species)
B 8.9a Groundwater hydrology on groundwater chemistry (by introducing water with diff. composition)
B 8.9b Groundwater hydrology on groundwater chemistry (by mixing and dilution)
N 9.15 Exchange (near-field water comp. on far-field water comp.)
N 10.9a Transport of species (near-field water flow on near-field water composition)
N 15.9b Exchange (far-field water comp. on near-field water comp)
F 2.6b Groundwater composition
F 2.12 Source term
F 7.6 Mixing
F 13.6 Infiltrating water

5.7.3 Diffusion

B 10.9e Nearfield rock on groundwater chemistry (by matrix diffusion)
N 7.9b Matrix diffusion (near-field rock on water composition in near-field rock)
N 7.9e Molecular diffusion (near-field rock on water composition in near-field rock)
N 12.9d Diffusion (near-field temperature on near-field water composition)

5.7.4 Reactions groundwater/rock matrix

B 9.10 Groundwater chemistry on nearfield rock (by affecting chemical equilibria)
B 10.9a Nearfield rock on groundwater chemistry (by affecting chemical equilibria)
B 10.9d Nearfield rock on groundwater chemistry (by sorption of ions)
B 7.9a Temperature of nearfield on groundwater chemistry (by affecting chemical equilibria)
B 7.9b Temperature of nearfield on groundwater chemistry (by affecting the rate of chem. changes)
N 7.9a Sorption (near-field rock on water composition in near-field rock)
N 7.9c Dissolution/precipitation (near-field rock on water composition in near-field rock)
N 9.7b Rock alteration (near-field water composition on near-field rock)
N 10.7b Solubility (near-field water flow on near-field rock)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 12.7c Kinetics (temperature in near-field rock on near-field rock)
N 12.7d Equlibria (temperature in near-field rock on near-field rock)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
F 4.6 Rock-water interaction
F 6.4 Groundwater rock interaction

5.7.5 Dissolution/precipitation of fracture-filling minerals
B 6.10b Gas in nearfield rock on nearfield rock (by reaction with fracture minerals)
B 7.9a Temperature of nearfield on groundwater chemistry (by affecting chemical equilibria)
B 7.9b Temperature of nearfield on groundwater chemistry (by affecting the rate of chem. changes)
B 7.10c Temperature of nearfield on nearfield rock (by affecting the rate of chemical changes)
B 7.10d Temperature of nearfield on nearfield rock (by affecting chemical equlibria)
B 9.10 Groundwater chemistry on nearfield rock (by affecting chemical equilibria)
B 10.9a Nearfield rock on groundwater chemistry (by affecting chemical equilibria)
B 10.9d Nearfield rock on groundwater chemistry (by sorption of ions)
N 7.9a Sorption (near-field rock on water composition in near-field rock)
N 7.9c Dissolution/precipitation (near-field rock on water composition in near-field rock)
N 7.14e Dissolution (near-field rock on radionuclides in near-field water)
N 9.7a Fracture alteration (near-field water composition on near-field rock)
N 9.11c Chemical reactions (near-field water composition on near-field gas)
N 9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)
N 10.7b Solubility (near-field water flow on near-field rock)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 12.7c Kinetics (temperature in near-field rock on near-field rock)
N 12.7d Equlibria (temperature in near-field rock on near-field rock)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
F 5.6a Dissolution of fracture minerals
F 5.6b Colloid generation
F 6.3b Precipitation/bacterial growth in the long run
F 6.5 Precipitation and dissolution of fracture minerals
F 6.11a Chemically generated gas
F 9.6 Dissolution and precipitation of minerals

5.7.6 Microbial processes
N 8.9b Stray materials (construction materials on near-field water composition)
N 9.11b Microbial activity (near-field water composition on near-field gas)
F 1.6b Stray materials
F 6.3a Precipitation/bacterial growth operating phase
F 6.3b Precipitation/bacterial growth in the long run
F 6.11b Microbially generated gas
F 11.6a pH and Eh affected
F 11.6b Eh affected

5.7.7 Decomposition of inorganic engineering material
B 7.11b Temperature of nearfield on reinforcements (by affecting chemical equilibria)
B 7.11c Temperature of nearfield on reinforcements (by affecting the rate of chemical changes)
B 9.11a Groundwater chemistry on reinforcements (by affecting chemical equilibria)
B 9.11b Groundwater chemistry on reinforcements (by cement maturation and gain in strength)
B 11.6a Reinforcements on nearfield gas (by producing gas)
B 11.9 Reinforcements on groundwater chemistry (by dissol. and influence on chemical equilibria)
N 8.11a Corrosion gases (construction materials on near-field gas)
N 8.9a Alteration (construction materials on near-field water composition)
N 9.8a Dissolution/corrosion (near-field water composition on construction materials)
N 12.9a Kinetics (near-field temperature on near-field water composition)
N 12.9b Equilibria (near-field temperature on near-field water composition)
F 1.6a Construction materials
F 1.11c Gas source

5.7.8 Colloid formation
B 10.9c Nearfield rock on groundwater chemistry (by colloid transport)
F 3.6b Colloid and particulate generation
F 4.6 Rock-water interaction
F 5.6b Colloid generation

5.7.9 Gas formation/dissolution
B 6.9 Gas in nearfield rock on groundwater chemistry (by being dissolved)
B 6.10b Gas in nearfield rock on nearfield rock (by reaction with fracture minerals)
B 9.6 Groundwater chemistry on nearfield gas (by affecting its solubility)
N 9.11a Gas dissolution (near-field water composition on near-field gas)
N 10.11b Gas dissolution (near-field water flow on near-field gas)
N 10.9b Solubility (near-field water flow on near-field water composition)
N 11.9a Gas dissolution (near-field gas on near-field water composition)
N 12.11b Gas dissolution (near-field temperature on near-field gas)
F 8.11a Gas solubility
F 9.11a Gas solubility
F 11.6a pH and Eh affected
F 11.6b Eh affected

5.7.10 Methane ice formation
F 6.11c Clathrates

5.7.11 Salt exclusion

5.8 Radionuclide transport

5.8.1 Advection and dispersion
N 10.14a Transport of dissolved RN (n-f water flow on radionucl. in near-field water)
N 14.15 Source term (radionuclides in near-field water on radionuclides in far-field)
F 2.12 Source term
F 7.12b Direction, distribution and magnitude
F 7.12c Hydrodynamic dispersion
F 12.13 Contamination

5.8.2 Sorption
N 7.14a Fracture sorption (near-field rock on radionuclides in near-field water)
N 7.14c Matrix sorption (near-field rock on radionuclides in near-field water)
N 7.14e Dissolution (near-field rock on radionuclides in near-field water)
N 9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)
N 9.14b Sorption/desorption (near-field water comp. on radionucl. in near-field water)
N 12.14a Kinetics (near-field temperature on radionuclides in near-field water)
N 14.7a Contamination (radionuclides in water in near-field rock on near-field rock)
F 3.12a Changed porosity and surface area
F 3.12b Sorption capacity
F 4.12a Sorption
F 5.12b Surface area
F 5.12c Sorption
F 9.12 Kinetic effects

5.8.3 Molecular diffusion and matrix diffusion
N 7.14b Matrix diffusion (near-field rock on radionuclides in near-field water)
N 7.14d Molecular diffusion (near-field rock on radionuclides in near-field water)
N 12.14c Diffusion (near-field temperature on radionuclides in near-field water)
F 3.12a Changed porosity and surface area
F 4.12b Matrix diffusion
F 5.12a Molecular diffusion
F 5.12b Surface area
F 6.12a Sorption and solubility
F 9.12 Kinetic effects
F 12.13 Contamination

5.8.4 Colloid transport
N 9.14c Colloid transport (near-field water comp. on radionucl. in near-field water)
F 6.12b Colloids and bacteria
F 7.12b Direction, distribution and magnitude
F 12.13 Contamination

5.8.5 Speciation
N 12.14b Equilibria (near-field temperature on radionuclides in near-field water)
F 6.12a Sorption and solubility

5.8.6 Transport in gas phase
N 9.14d Dissolution of radioactive gas (n-f wat. comp. on radionucl. in near-field water)
N 10.14b Transport of dissolved gas (n-f water flow on radionucl. in near-field water)
N 11.14a Colloids on gas bubbles (near-field gas on radionuclides in near-field water)
N 11.14b Dissolution of radioactive gas (near-field gas on radionucl. in n-f water)
N 11.15c Radioactive gas (near-field gas on far-field gas)
N 14.11 Dissolution/evaporation (radionuclides in near-field water on near-field gas)
F 7.12a Transport of dissolved gas
F 11.12 Colloid sorption on gas bubbles
F 11.13 Gas release
F 12.13 Contamination

5.8.7 Radioactive decay

Initial state and affects initial state for the safety analysis

B 2.1 Canister on fuel (by affecting confinement through changes in physical state)
B 2.8 Canister on groundwater hydrology (geo- metrical restraint)
B 3.6a Buffer on buffer gas (by capacity of storing gas)
B 3.8 Buffer on groundwater hydrology (by affecting flow in nearfield rock)
B 10.3d Nearfield rock on buffer (by aff. its homogeneity through changes of the depos. hole geometry)
N 2.1 Confinement (steel canister on fuel)
N 3.10b Intersects flowpaths (copper canister on water flow in near-field rock)
N 3.2a Confinement (copper canister on steel canister)
N 5.10a Intersects flow paths (buffer on water flow in near-field rock)
N 6.13b Tunnel dimensions (backfill on near-field rock stresses)
N 10.8c Grouting (near-field water flow on construction materials)
F 1.2 Excavation method
F 1.3a Excavation method
F 1.5 Displacement effects
F 1.8 Drawdown effects
F 1.9a Repository depth
F 1.9b Ventilation
F 1.10 Tunnel dimensions
F 1.11a Ventilation
F 1.11b Blasting gas
F 2.1a Swelling ability
F 2.1b Heat
F 2.7a Changed flow around holes
F 3.1a Excavation method
F 3.1b Amount of reinforcement
F 3.11a Indiffusion of air
F 4.1 Layout/construction method
F 4.3 Magnitude and geometrical extent
F 4.5 Fracture characteristics and infilling mineralisation
F 4.10 Genesis, tectonic history and rock type
F 5.1a Avoid major fracture zones
F 5.1b Constructability
F 5.3 Mechanical properties and fracture frequency
F 6.1a Depth affected by redox potential
F 6.1b Construction materials
F 6.3a Precipitation/bacterial growth operating phase
F 7.1a Canister positioning
F 7.1b Construction methods
F 8.1 Construction methods
F 10.1a Design/layout
F 10.1b Construction methods
F 11.1 Ventilation problems
F 12.1 Design/layout
F 13.1 Siting - Design/Layout

Not included in the Process Report
B 1.5 Fuel on buffer non-smectite minerals/impurities in buffer (by radiation)
B 1.10 Fuel on nearfield rock (by radiation)
B 1.11 Fuel on reinforcements (by radiation)
B 2.3b Canister on buffer (by affecting the density through thermally induced geometrical changes)
B 3.5 Buffer on buffer non-smectite minerals/ impurities (by affecting their positions)
B 3.7b Buffer on buffer temperature (by heat of wetting)
B 3.11a Buffer on reinforcements (by destruction of cement grout in fractures in deposition holes)
B 3.11b Buffer on reinforcements (by consolidation of bentonite grout in fractures in depostion holes)
B 4.7b Buffer porewater on buffer temperature (by heat of wetting)
B 5.2 Buffer non-smectite minerals/impurities on canister (by corroding contacting canister)
B 5.3 Buffer non-smectite mineral/impurities on buffer smectite (by degrading contacting smectite)
B 6.4b Buffer gas on buffer porewater (by pressurizing)
B 6.5 Buffer gas on buffer non-smectite minerals/impurities (by chemical reactions)
B 6.11 Gas in nearfield rock and backfill on reinforcements (by pressurizing)
B 7.1 Temperature of fuel on fuel (by causing structural alteration)
B 7.4e Temperature of buffer temperature on buffer porewater (by affecting ion mobility)
B 7.11a Temperature of nearfield on reinforcements (by affecting their physical performance)
B 8.10a Groundwater hydrology on nearfield rock (by erosion)
B 8.10b Groundwater hydrology on nearfield rock (by particle transport)
B 8.11a Groundwater hydrology on reinforcements (by erosion)
B 8.11b Groundwater hydrology on reinforcements (by pressurizing)
B 10.4 Nearfield rock on buffer porewater (by influence of earth currents)
B 10.9b Nearfield rock on groundwater chemistry (by influence of earth currents)
B 10.11 Nearfield rock on reinforcements (by imposing stress/strain)
B 11.2 Reinforcements on canister (by being lost in deposition holes)
B 11.3 Reinforcements on buffer (by providing confinement)
B 11.6b Reinforcement on nearfield gas (by storing gas)
B 11.7 Reinforcements on nearfield temperature (by heat transport)
B 11.8 Reinforcements on groundwater hydrology (by being permeable and affect. flow in nearfield rock)
B 11.10 Reinforcements on nearfield rock (by affecting its stability)
B 11.12 Reinforcements on backfill (by providing confinement through lateral support)
B 12.11 Backfill on reinforcements (by affecting their stability through pressurizing)
N 1.3b Neutron activation (fuel on copper canister)
N 1.7 Radiation (fuel on near-field rock)
N 1.8 Radiation (fuel on construction materials)
N 2.14d Dissolution (steel canister on radionuclides in the water in the canister)
N 3.14d Dissolution (copper canister on radionuclides in the water in the canister)
N 4.11 Gas expansion/compression (voids in canister on gas in canister)
N 5.8 Mechanical impact (buffer on construction materials)
N 5.14e Dissolution (buffer on radionuclides in buffer porewater)
N 6.7 Intrusion (backfill on near-field rock)
N 6.8 Mechanical impact (backfill on construction materials)
N 6.9e Colloid filter (backfill on near-field water composition)
N 6.14d Dissolution (backfill on radionuclides in backfill water)
N 7.8 Reinforcements (near-field rock on construction materials)
N 7.9d Earth currents (near-field rock on near-field water composition)
N 8.3 Mechanical impact (construction materials on copper canister)
N 8.5 Confinement (construction materials on buffer)
N 8.6 Confinement (construction materials on backfill)
N 8.7 Mechanical support (rock reinforcements on near-field rock)
N 8.10 Flow pattern (construction materials on near-field water flow)
N 8.11b Gas inclusion (construction materials on near-field gas)
N 8.12 Heat transport (construction materials on near-field temperature)

N 8.14a Sorption/desorption (construction materials on radionucl. in near-field water)
N 8.14b Diffusion (construction materials on radionuclides in near-field water)
N 8.14c Dissolution (construction materials on radionuclides in near-field water)
N 9.8b Maturation (near-field water composition on construction materials)
N 10.7a Erosion/sedimentation (near-field water flow on near-field rock)
N 10.8a Erosion (near-field water flow on construction materials)
N 10.8b Solubility (near-field water flow on construction materials)
N 10.14c Solubility (near-field water flow on radionuclides in near-field water)
N 11.1b H2 catalysis (gas in canister on fuel)
N 11.5c Porewater pressure (gas inside buffer on buffer)
N 11.5e Chemical reactions (gas in buffer on buffer)
N 11.7b Chemical reactions (gas in near-field rock on near-field rock)
N 11.8 Mechanical impact (near-field gas on construction materials)
N 12.1a Structural/chemical alteration (temperature in canister on fuel)
N 12.1d Volatility and migration (temperature in canister on fuel)
N 12.1e Expansion/contraction (temperature in canister on fuel cladding)
N 12.8a Expansion/contraction (near-field temperature on construction materials)
N 12.8b Kinetics (near-field temperature on construction materials)
N 12.8c Equilibria (near-field temperature on construction materials)
N 12.9c Phase changes (near-field temperature on near-field water comp.)
N 12.9e Gradient transport (near-field temperature on near-field water comp.)
N 12.14d Gradient transport (near-field temperature on radionuclides in n-f water)
N 13.8 Deformations (near-field rock stresses on construction materials)
N 13.15 Stress (near-field rock stresses on far-field rock stresses)
N 14.7b Radiation effects (radionuclides in water in near-field rock on near-field rock)
N 14.8a Contamination (radionuclides in near-field water on construction materials)
N 14.8b Radiation effects (radionuclides in near-field water on construction materials)
N 14.9a Contamination (radionuclides in near-field water on near-field water comp.)
N 14.9c Radiolysis (radionuclides in near-field water on near-field water composition)
N 14.12 Decay heat (radionuclides in near-field water on near-field temperature)
N 15.9a Earth currents (far-field rock prop on near-field water comp.)
N 15.11b Composition (far-field gas on near-field gas)
N 15.14 Natural radionuclides (RN in far-field water on RN in near-field water)
F 1.3b Grouting
F 1.3c Reinforcement
F 1.13a Industrial facility
F 1.13b Dumps
F 3.6a Changed porosity and surface area
F 4.11 Radon generation
F 4.13a Land use
F 4.13b Potential human intrusion
F 5.10 Stress magnitude and orientation
F 6.9 Heat conductivity
F 6.13a Water use
F 6.13b Biotopes
F 7.3 Erosion
F 7.5 Erosion and sedimentation
F 8.6 Solubility
F 8.13 Potential effect on vegetation
F 10.8 Confined aquifers
F 10.13 Mechanical stability
F 11.9 Gas law
F 12.6a Radiolysis
F 13.8b Tidal driving forces
F 13.10b Erosion

Coupling of the buffer interactions to the headings in the Process Report.

The diagonal elements and the interactions with priority =0 are not listed.

1.2 Fuel on canister (by radiation)
3.7.4 Radiation effects

1.3 Fuel on buffer smectite (by radiation)
4.7.8 Radiation-induced montmorillonite transformation

1.4 Fuel on buffer porewater (by radiolysis)
4.7.9 Radiolysis of pore water

1.5 Fuel on buffer non-smectite minerals/impurities in buffer (by radiation)
Not included in the Process Report

1.6 Fuel on nearfield gas (by radiation)
3.7.5 Corrosion of copper canister

1.7 Fuel on nearfield temperature (by radioactive decay)
2.3.2 Radiation attenuation/heat generation

1.9 Fuel on groundwater chemistry in nearfield
4.7.9 Radiolysis of pore water

1.10 Fuel on nearfield rock (by radiation)
Not included in the Process Report

1.11 Fuel on reinforcements (by radiation)
Not included in the Process Report

1.12 Fuel on backfill (by radiation)
4.7.8 Radiation-induced montmorillonite transformation

2.1 Canister on fuel (by affecting confinement through changes in physical state)
Initial state and affects initial state for the safety analysis

2.3a Canister on buffer (by affecting the density through pressurizing)
4.6.3 Mechanical interaction buffer/canister

2.3b Canister on buffer (by affecting the density through thermally induced geometrical changes)
Not included in the Process Report

2.4 Canister on buffer porewater (by ion release)
3.7.1 Corrosion of cast iron insert
3.7.2 Galvanic corrosion
3.7.3 Stress corrosion cracking of cast iron insert
3.7.5 Corrosion of copper canister
3.7.6 Stress corrosion cracking, copper canister

2.6 Canister on nearfield gas (by corrosion)
3.7.1 Corrosion of cast iron insert
4.5.3 Gas transport/dissolution

2.7 Canister on nearfield temperature (by transfer of heat from fuel)
3.4.1 Heat transport

2.8 Canister on groundwater hydrology (geo- metrical restraint)
Initial state and affects initial state for the safety analysis

3.2a Buffer on canister (by affecting its position through swelling pressure anomalies)
4.6.3 Mechanical interaction buffer/canister

3.2b Buffer on canister (by affecting its shape through swelling pressure)
3.6.3 Deformation of copper canister from external pressure
4.6.3 Mechanical interaction buffer/canister

3.2c Buffer on canister (by affecting position and shape through shearing)
4.6.3 Mechanical interaction buffer/canister

3.4a Buffer on buffer porewater (by ion diffusion)
4.7.3 Diffusion

3.4b Buffer on buffer porewater (by affecting its physical state)
4.6.1 Swelling
4.7.10 Microbial processes
4.7.4 Ion exchange/sorption

3.4c Buffer on buffer porewater (by dissolution of smectite)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

3.4d Buffer on buffer porewater (by ion exchange)
4.7.4 Ion exchange/sorption

3.4e Buffer on buffer porewater (by producing colloids)
4.7.7 Colloid release/erosion

3.4f Buffer on buffer porewater (by sorption)
4.7.4 Ion exchange/sorption

3.4g Buffer on buffer porewater (by flow)
4.7.2 Advection

3.4h Buffer on buffer porewater (by affecting the pressure state)
4.5.1 Water transport under unsaturated conditions

3.5 Buffer on buffer non-smectite minerals/ impurities (by affecting their positions)
Not included in the Process Report

3.6a Buffer on buffer gas (by capacity of storing gas)
Initial state and affects initial state for the safety analysis

3.6b Buffer on buffer gas pressure (by release of gas)
4.5.3 Gas transport/dissolution

3.6c Buffer on buffer gas (by gas conductivity)
4.5.3 Gas transport/dissolution

3.7a Buffer on buffer temperature (by heat flow)
4.4.1 Heat transport

3.7b Buffer on buffer temperature (by heat of wetting)
Not included in the Process Report

3.8 Buffer on groundwater hydrology (by affecting flow in nearfield rock)
Initial state and affects initial state for the safety analysis

3.10a Buffer on nearfield rock (by affecting the stability through swelling pressure)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.4 Reactivation-movement along existing fractures

3.10b Buffer on nearfield rock (by affecting frac- ture aperture through swelling pressure)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.4 Reactivation-movement along existing fractures

3.10c Buffer on nearfield rock (by self-sealing)
4.6.1 Swelling
4.6.4 Mechanical interaction buffer/near-field rock
4.7.7 Colloid release/erosion

3.11a Buffer on reinforcements (by destruction of cement grout in fractures in deposition holes)
Not included in the Process Report

3.11b Buffer on reinforcements (by consolidation of bentonite grout in fractures in depostion holes)
Not included in the Process Report

3.12 Buffer on backfill (by swelling pressure)
4.6.2 Mechanical interaction buffer/backfill

4.2a Buffer porewater on canister (by corrosion)
3.7.5 Corrosion of copper canister

4.2b Buffer porewater on canister (by pressurizing canister)
3.6.3 Deformation of copper canister from external pressure
4.6.3 Mechanical interaction buffer/canister

4.3a Buffer porewater on buffer (by producing swelling pressure and expandability)
4.6.1 Swelling

4.3b Buffer porewater on buffer (by dissolution of the smectite content)
4.7.5 Montmorillonite transformation

4.3c Buffer porewater on buffer smectite (by formation of smectite)
4.7.5 Montmorillonite transformation

4.3d Buffer porewater on buffer smectite (by ion-exchange)
4.7.4 Ion exchange/sorption

4.3e Buffer porewater on buffer smectite (by degrading and alterating it)
4.7.5 Montmorillonite transformation

4.3f Buffer porewater on buffer (by affecting the microstructural homogeneity)
4.6.1 Swelling
4.7.4 Ion exchange/sorption

4.5a Buffer porewater on buffer non-smectite minerals/ impurities (by dissolution)
4.7.6 Dissolution/precipitation of impurities

4.5b Buffer porewater on buffer non-smectite minerals/impurities (by precipitation)
4.7.6 Dissolution/precipitation of impurities

4.6a Buffer porewater on buffer gas (by vapor pressure)
4.5.1 Water transport under unsaturated conditions

4.6b Buffer porewater on buffer gas (by dissolution of gas in porewater)
4.5.3 Gas transport/dissolution

4.6c Buffer porewater on buffer gas (by affecting the mobility of gas)
4.5.1 Water transport under unsaturated conditions

4.6d Buffer porewater on buffer gas (by affecting the pressure for release of gas)
4.5.3 Gas transport/dissolution

4.6e Buffer porewater on buffer gas (by microbial activity)
4.7.10 Microbial processes

4.7a Buffer porewater on buffer temperature (by heat conductivity)
4.4.1 Heat transport

4.7b Buffer porewater on buffer temperature (by heat of wetting)
Not included in the Process Report

4.8 Buffer porewater on groundwater hydrology (by exerting pressure)
4.5.1 Water transport under unsaturated conditions
4.6.6 Thermal expansion

4.9 Buffer porewater on groundwater chemistry (by supplying or extracting dissolved species)
5.7.2 Advection/mixing

4.10 Buffer porewater on nearfield rock (by exerting pressure on the rock)
4.6.6 Thermal expansion

4.12 Buffer porewater on backfill (by affecting its porewater pressure)
4.5.1 Water transport under unsaturated conditions
4.6.6 Thermal expansion

5.2 Buffer non-smectite minerals/impurities on canister (by corroding contacting canister)
Not included in the Process Report

5.3 Buffer non-smectite mineral/impurities on buffer smectite (by degrading contacting smectite)
Not included in the Process Report

5.4a Buffer non-smectite minerals/impurities on buffer porewater (by being dissolved)
4.7.6 Dissolution/precipitation of impurities

5.4b Buffer non-smectite minerals/impurities on buffer porewater (by being precipitated)
4.7.6 Dissolution/precipitation of impurities

5.4c Buffer non/smectite minerals/impurities on buffer porewater (by forming colloids)
4.7.6 Dissolution/precipitation of impurities

5.7 Buffer non-smect. min./ impurities on buffer/canister temperature (by affect. heat conductivity)
4.4.1 Heat transport

6.2a Buffer gas on canister (by pressurization)
4.6.3 Mechanical interaction buffer/canister

6.2b Buffer gas on canister (by corrosion)
3.7.3 Stress corrosion cracking of cast iron insert
3.7.5 Corrosion of copper canister
3.7.6 Stress corrosion cracking, copper canister

6.3a Buffer gas on buffer (by piping)
4.5.3 Gas transport/dissolution

6.3b Buffer gas on buffer (by affecting its homogeneity, i.a. through forming flow paths)
4.5.3 Gas transport/dissolution

6.3c Buffer gas on buffer (by affecting the hydration state)
4.5.3 Gas transport/dissolution

6.4a Buffer gas on buffer porewater (by being dissolved)
4.5.3 Gas transport/dissolution

6.4b Buffer gas on buffer porewater (by pressurizing)
Not included in the Process Report

6.5 Buffer gas on buffer non-smectite minerals/impurities (by chemical reactions)
Not included in the Process Report

6.7 Buffer gas on buffer/canister temperature (by thermal isolation)
4.4.1 Heat transport

6.8 Gas in nearfield rock on groundwater hydrology (by affecting the flow paths)
5.5.2 Gas flow/dissolution

6.9 Gas in nearfield rock on groundwater chemistry (by being dissolved)
5.7.9 Gas formation/dissolution

6.10a Gas in nearfield rock on nearfield rock (by affecting the degree of water saturation)
5.5.2 Gas flow/dissolution

6.10b Gas in nearfield rock on nearfield rock (by reaction with fracture minerals)
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.9 Gas formation/dissolution

6.11 Gas in nearfield rock and backfill on reinforcements (by pressurizing)
Not included in the Process Report

6.12a Gas in backfill on backfill (by affecting the degree of water saturation)
4.5.1 Water transport under unsaturated conditions

6.12b Gas in backfill on backfill (by causing piping and erosion)
4.5.3 Gas transport/dissolution

7.1 Temperature of fuel on fuel (by causing structural alteration)
Not included in the Process Report

7.2a Temperature of canister on canister (by changing its size and shape)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

7.2b Temperature of canister on canister (by affecting its material structure)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

7.2c Temperature of canister on canister (by internal pressurizing)
2.6.1 Thermal expansion/cladding failure

7.3a Temperature of buffer on buffer (by affecting the hydraulic conductivity)
4.5.2 Water transport under saturated conditions

7.3b Temperature of buffer on buffer (by affecting its thermal properties)
4.4.1 Heat transport

7.3c Temperature of buffer on buffer (by affecting its swelling pressure)
4.6.6 Thermal expansion

7.3d Buffer temperature on buffer (by affecting its total pressure)
4.6.6 Thermal expansion

7.3e Temperature of buffer on buffer (by affecting its shear strength)
4.6.6 Thermal expansion

7.3f Temperature of buffer on buffer smectite (by affecting chemical equilibria)
4.7.5 Montmorillonite transformation

7.3g Temperature of buffer on buffer (by affecting the rate of alteration of the smectite)
4.7.5 Montmorillonite transformation

7.4a Temperature of buffer on buffer porewater (by redistribution)
4.5.1 Water transport under unsaturated conditions

7.4b Temperature of buffer on buffer porewater (by affecting the viscosity)
4.5.2 Water transport under saturated conditions

7.4c Temperature of buffer on buffer porewater (by affecting the rate of chemical reactions)
4.7.4 Ion exchange/sorption
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

7.4d Temperature of buffer on buffer porewater (by determining the state of chemical equilibrium)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

7.4e Temperature of buffer temperature on buffer porewater (by affecting ion mobility)
Not included in the Process Report

7.4f Temperature of buffer on buffer porewater (by affecting its pressure)
4.6.6 Thermal expansion

7.5a Temperature of buffer on buffer non-smectite minerals/impurities (by affect. chemical equilibria)
4.7.6 Dissolution/precipitation of impurities

7.5b Temperature of buffer on buffer non-smectite miner./impurities (by affecting the rate of change)
4.7.6 Dissolution/precipitation of impurities

7.6a Temperature of buffer on buffer gas (by affecting its pressure)
4.5.1 Water transport under unsaturated conditions

7.6b Temperature on buffer gas (by vapor transport)
4.5.1 Water transport under unsaturated conditions

7.6c Temperature of buffer on buffer gas (by affecting gas solubility)
4.5.3 Gas transport/dissolution

7.8a Temperature of nearfield on groundwater hydrology (by groundwater convection)
5.5.1 Groundwater flow

7.8b Temperature of nearfield on groundwater hydrology (by affecting the viscosity)
5.5.1 Groundwater flow

7.9a Temperature of nearfield on groundwater chemistry (by affecting chemical equilibria)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.9b Temperature of nearfield on groundwater chemistry (by affecting the rate of chem. changes)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.10a Temperature of nearfield on nearfield rock (by affecting the structure)
5.6.3 Thermal movement
5.6.4 Reactivation-movement along existing fractures

7.10b Temperature of nearfield on nearfield rock (by affecting the mechanical stability)
5.6.3 Thermal movement
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

7.10c Temperature of nearfield on nearfield rock (by affecting the rate of chemical changes)
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.10d Temperature of nearfield on nearfield rock (by affecting chemical equlibria)
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.11a Temperature of nearfield on reinforcements (by affecting their physical performance)
Not included in the Process Report

7.11b Temperature of nearfield on reinforcements (by affecting chemical equilibria)
5.7.7 Decomposition of inorganic engineering material

7.11c Temperature of nearfield on reinforcements (by affecting the rate of chemical changes)
5.7.7 Decomposition of inorganic engineering material

7.12a Temperature of nearfield on backfill (by affecting chemical equilibria)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

7.12b Temperature of nearfield on backfill (by affecting the rate of chemical changes)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

7.12c Temperature of nearfield on backfill (by affecting its hydraulic conductivity)
4.5.2 Water transport under saturated conditions

8.3a Groundwater hydrology on buffer smectite (by eroding smectite that has entered fractures)
4.7.7 Colloid release/erosion

8.3b Groundwater hydrology on buffer (by providing water for saturation)
4.5.1 Water transport under unsaturated conditions

8.3c Groundwater hydrology on buffer (by affecting pressure heads and hence conditions for saturat.)
4.5.1 Water transport under unsaturated conditions

8.4 Groundwater hydrology on buffer porewater (by affecting its chemical composition)
4.7.2 Advection

8.5 Groundwater hydrology on buffer non-smectite minerals/impurities (by erosion of buffer)
4.7.7 Colloid release/erosion

8.6a Groundwater hydrology on nearfield gas (by aff. water pressure in the nearf. rock and backfill)
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution

8.6b Groundwater hydrology on nearfield gas (by affect. gas migration in nearfield rock and backfill)
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution

8.7 Groundwater hydrology on nearfield temperature (by heat transport through convection)
4.4.1 Heat transport
5.4.1 Heat transport

8.9a Groundwater hydrology on groundwater chemistry (by introducing water with diff. composition)
4.7.2 Advection
5.7.2 Advection/mixing

8.9b Groundwater hydrology on groundwater chemistry (by mixing and dilution)
4.7.2 Advection
5.7.2 Advection/mixing

8.10a Groundwater hydrology on nearfield rock (by erosion)
Not included in the Process Report

8.10b Groundwater hydrology on nearfield rock (by particle transport)
Not included in the Process Report

8.11a Groundwater hydrology on reinforcements (by erosion)
Not included in the Process Report

8.11b Groundwater hydrology on reinforcements (by pressurizing)
Not included in the Process Report

8.12a Groundwater hydrology on backfill (by piping and erosion)
4.7.7 Colloid release/erosion

8.12b Groundwater hydrology on backfill (by providing water for saturation)
4.5.1 Water transport under unsaturated conditions

9.4 Groundwater chemistry on buffer porewater (by affecting its chemical composition)
4.7.2 Advection
4.7.3 Diffusion

9.6 Groundwater chemistry on nearfield gas (by affecting its solubility)
4.5.3 Gas transport/dissolution
5.7.9 Gas formation/dissolution

9.7 Groundwater chemistry on nearfield temp. (by affecting the heat conductivity of nearfield water)
4.4.1 Heat transport
5.4.1 Heat transport

9.8a Groundwater chemistry on groundwater hydrology (by buoyancy effects)
4.5.2 Water transport under saturated conditions
5.5.1 Groundwater flow

9.8b Groundwater chemistry on groundwater hydrology (by affecting water viscosity)
5.5.1 Groundwater flow

9.10 Groundwater chemistry on nearfield rock (by affecting chemical equilibria)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

9.11a Groundwater chemistry on reinforcements (by affecting chemical equilibria)
5.7.7 Decomposition of inorganic engineering material

9.11b Groundwater chemistry on reinforcements (by cement maturation and gain in strength)
5.7.7 Decomposition of inorganic engineering material

9.12a Groundwater chemistry on backfill (by affecting chemical equilibria)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

9.12b Groundwater chemistry on backfill (by sorption)
4.7.4 Ion exchange/sorption

10.3a Nearfield rock on buffer (by affecting confining function)
4.6.1 Swelling
4.6.4 Mechanical interaction buffer/near-field rock

10.3b Nearfield rock on buffer (by imposing shear strain)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.4 Reactivation-movement along existing fractures

10.3c Nearfield rock on buffer (by reducing its density through loss of buffer into fractures)
4.6.1 Swelling
4.7.7 Colloid release/erosion

10.3d Nearfield rock on buffer (by aff. its homogeneity through changes of the depos. hole geometry)
Initial state and affects initial state for the safety analysis

10.3e Nearfield rock on buffer (by aff. its density through time-dep. convergence of the dep. holes)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.6 Time-dependent deformations

10.4 Nearfield rock on buffer porewater (by influence of earth currents)
Not included in the Process Report

10.6a Nearfield rock on nearfield gas (by controlling the release of gas)
5.5.2 Gas flow/dissolution

10.6b Nearfield rock on nearfield gas (by storing gas)
5.5.2 Gas flow/dissolution

10.7 Nearfield rock on nearfield temperature (by aff. heat transport through its thermal conductivity)
5.4.1 Heat transport

10.8 Nearfield rock on groundwater hydrology (by its structural constitution)
5.5.1 Groundwater flow

10.9a Nearfield rock on groundwater chemistry (by affecting chemical equilibria)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

10.9b Nearfield rock on groundwater chemistry (by influence of earth currents)
Not included in the Process Report

10.9c Nearfield rock on groundwater chemistry (by colloid transport)
5.7.8 Colloid formation

10.9d Nearfield rock on groundwater chemistry (by sorption of ions)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

10.9e Nearfield rock on groundwater chemistry (by matrix diffusion)
5.7.3 Diffusion

10.11 Nearfield rock on reinforcements (by imposing stress/strain)
Not included in the Process Report

10.12a Nearfield rock on backfill (by providing confinement)
4.6.5 Mechanical interaction backfill/near-field rock

10.12b Nearfield rock on backfill (by reduction of density through loss of backfill into fractures)
4.7.7 Colloid release/erosion

11.2 Reinforcements on canister (by being lost in deposition holes)
Not included in the Process Report

11.3 Reinforcements on buffer (by providing confinement)
Not included in the Process Report

11.6a Reinforcements on nearfield gas (by producing gas)
5.7.7 Decomposition of inorganic engineering material

11.6b Reinforcement on nearfield gas (by storing gas)
Not included in the Process Report

11.7 Reinforcements on nearfield temperature (by heat transport)
Not included in the Process Report

11.8 Reinforcements on groundwater hydrology (by being permeable and affect. flow in nearfield rock)
Not included in the Process Report

11.9 Reinforcements on groundwater chemistry (by dissol. and influence on chemical equilibria)
5.7.7 Decomposition of inorganic engineering material

11.10 Reinforcements on nearfield rock (by affecting its stability)
Not included in the Process Report

11.12 Reinforcements on backfill (by providing confinement through lateral support)
Not included in the Process Report

12.3 Backfill on buffer (by providing confinement)
4.6.2 Mechanical interaction buffer/backfill

12.6a Backfill on nearfield gas (by affecting its pressure)
4.5.3 Gas transport/dissolution

12.6b Backfill on nearfield gas (by storing gas)
4.5.1 Water transport under unsaturated conditions
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution

12.7 Backfill on nearfield temperature (by heat flow)
4.4.1 Heat transport

12.8 Backfill on groundwater hydrology (by distribution of flow in and through the backfill)
4.5.1 Water transport under unsaturated conditions
4.5.2 Water transport under saturated conditions

12.9a Backfill on groundwater chemistry (by diss. of minerals and affecting chemical equilibria)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

12.9b Backfill on groundwater chemistry (by sorption)
4.7.4 Ion exchange/sorption

12.10a Backfill on nearfield rock (by affecting its structure through pressurizing)
4.6.5 Mechanical interaction backfill/near-field rock

12.10b Backfill on nearfield rock (by affecting its stability through pressurizing)
4.6.5 Mechanical interaction backfill/near-field rock

12.10c Backfill on nearfield rock (by penetrating into and sealing fractures)
4.7.7 Colloid release/erosion

12.11 Backfill on reinforcements (by affecting their stability through pressurizing)
Not included in the Process Report

Coupling of the near-field interactions to the headings in the Process Report.

The diagonal elements and the interactions with priority =0 are not listed.

1.2a Radiation (fuel on steel canister)
3.7.4 Radiation effects

1.2b Neutron activation (fuel on steel canister)
3.7.4 Radiation effects

1.3a Radiation (fuel on copper canister)
3.7.4 Radiation effects

1.3b Neutron activation (fuel on copper canister)
Not included in the Process Report

1.4a Dissolution/precipitation (fuel on voids in canister)
2.7.5 Fuel dissolution

1.4b Cladding corrosion (fuel on voids in canister)
2.7.4 Metal corrosion

1.5 Radiation (fuel on buffer)
4.7.8 Radiation-induced montmorillonite transformation

1.6 Radiation (fuel on backfill)
4.7.8 Radiation-induced montmorillonite transformation

1.7 Radiation (fuel on near-field rock)
Not included in the Process Report

1.8 Radiation (fuel on construction materials)
Not included in the Process Report

1.9a Radiolysis (fuel on water composition outside the canister)
4.7.9 Radiolysis of pore water

1.9b Radiolysis (fuel on water composition inside canister)
2.7.3 Water radiolysis
2.7.5 Fuel dissolution

1.9c Oxidant sink (fuel on water composition in canister)
2.7.5 Fuel dissolution

1.9d Fuel dissolution (fuel on water composition in canister)
2.7.8 Speciation of radionuclides, colloid formation

1.9e Cladding corrosion (fuel on water composition in the canister)
2.7.4 Metal corrosion

1.11a Helium production (fuel on gas inside canister)
2.7.9 Helium production

1.11b Radiolysis (fuel on gas inside canister)
2.7.2 Residual gas radiolysis/acid formation

1.11c Radiolysis (fuel on gas outside canister)
3.7.5 Corrosion of copper canister

1.11d Cladding corrosion (fuel on gas inside canister)
2.7.4 Metal corrosion

1.11e Radioactive gas (fuel on radioactive gas in canister)
2.8 Radionuclide transport

1.12 Decay heat (fuel on near-field temperature)
2.3.2 Radiation attenuation/heat generation

1.14a Dissolution/precipitation (fuel on radionuclides in water in canister)
2.7.5 Fuel dissolution
2.7.8 Speciation of radionuclides, colloid formation

1.14b Instant release (fuel on radionuclides in water in canister)
2.7.6 Dissolution of gap inventory
2.7.8 Speciation of radionuclides, colloid formation

1.14c Cladding corrosion (fuel on water in canister)
2.7.4 Metal corrosion

2.1 Confinement (steel canister on fuel)
Initial state and affects initial state for the safety analysis

2.3 Yawning (steel canister on copper canister)
3.6.5 Deformation from internal corrosion products

2.4a Corrosion products (steel canister on voids in canister)
3.6.5 Deformation from internal corrosion products
3.7.1 Corrosion of cast iron insert

2.4b Void size (steel canister on voids in canister)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

2.9 Corrosion (steel canister on water composition in canister)
2.7.7 Speciation of iron corrosion products
3.7.1 Corrosion of cast iron insert

2.10 Integrity (steel canister on water flow through canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

2.11a Corrosion gas (steel canister on gas in canister)
3.7.1 Corrosion of cast iron insert

2.11b Gas release (steel canister on gas in canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

2.12 Heat transport (steel canister on temperature in near-field)
3.4.1 Heat transport

2.14a Sorption/desorption (steel canister on radionuclides in water in canister)
2.8 Radionuclide transport

2.14b Diffusion (steel canister on radionuclides in near-field water)
2.8 Radionuclide transport

2.14c Colloid filter (steel canister on radionuclides in near-field water)
2.8 Radionuclide transport

2.14d Dissolution (steel canister on radionuclides in the water in the canister)
Not included in the Process Report

3.2a Confinement (copper canister on steel canister)
Initial state and affects initial state for the safety analysis

3.2b Galvanic corrosion (copper canister on steel canister)
3.7.2 Galvanic corrosion

3.4 Void size (copper canister on voids in canister)
3.6.3 Deformation of copper canister from external pressure
3.6.4 Thermal expansion (both cast iron insert and copper canister)

3.5a Density (canister on buffer)
4.6.3 Mechanical interaction buffer/canister

3.5b Expansion/compression (copper canister on buffer)
4.6.3 Mechanical interaction buffer/canister

3.9 Corrosion (copper canister on water composition in buffer and in canister)
3.7.5 Corrosion of copper canister

3.10a Integrity (copper canister on water flow through canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

3.10b Intersects flowpaths (copper canister on water flow in near-field rock)
Initial state and affects initial state for the safety analysis

3.11 Gas release (copper canister on gas inside canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

3.12 Heat transport (copper canister on near-field temperature)
3.4.1 Heat transport

3.14a Sorption/desorption (copper canister on radionuclides in the water in the canister)
2.8 Radionuclide transport

3.14b Diffusion (copper canister on radionuclides in near-field water)
2.8 Radionuclide transport

3.14c Colloid filter (copper canister on radionuclides in near-field water)
2.8 Radionuclide transport

3.14d Dissolution (copper canister on radionuclides in the water in the canister)
Not included in the Process Report

4.1a Fuel alteration (voids in canister on fuel)
2.7.5 Fuel dissolution

4.1b Fuel dissolution/precipitation (voids in canister on fuel)
2.7.5 Fuel dissolution

4.1c Cladding corrosion (voids in canister on fuel)
2.7.4 Metal corrosion

4.1d Solubility (voids in canister on fuel)
2.7.8 Speciation of radionuclides, colloid formation

4.2a External corrosion (voids in canister on steel canister)
3.7.1 Corrosion of cast iron insert

4.2b Internal corrosion (voids in canister on steel canister)
3.7.1 Corrosion of cast iron insert

4.2c Solubility (voids in canister on steel canister)
2.7.7 Speciation of iron corrosion products

4.3 Mechanical stability (voids in canister on copper canister)
3.6.3 Deformation of copper canister from external pressure

4.5 Buffer intrusion (steel canister on buffer)
4.6.3 Mechanical interaction buffer/canister

4.9a Solubility (voids in canister on water composition in canister)
2.7.7 Speciation of iron corrosion products
2.7.8 Speciation of radionuclides, colloid formation

4.9b Extent of reactions (voids in canister on water composition in canister)
2.7.3 Water radiolysis
2.7.4 Metal corrosion
2.7.5 Fuel dissolution

4.10 Internal water pressure (voids in canister on near-field water flow)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

4.11 Gas expansion/compression (voids in canister on gas in canister)
Not included in the Process Report

4.12 Heat transport (voids in canister on near-field temperature)
2.4.1 Heat transport

4.14a Solubility (voids in canister on radionuclides in water in canister)
2.7.8 Speciation of radionuclides, colloid formation

4.14b Extent of reactions (voids in canister on radionuclides in water in canister)
2.7.5 Fuel dissolution
2.8 Radionuclide transport

4.14c Volume effect on IRF (voids in canister on radionuclides in water in canister)
2.7.6 Dissolution of gap inventory

5.3a Confinement (buffer on copper canister)
4.6.3 Mechanical interaction buffer/canister

5.3b Swelling pressure (buffer on copper canister)
3.6.3 Deformation of copper canister from external pressure
4.6.3 Mechanical interaction buffer/canister

5.3c Shear (buffer on copper canister)
4.6.3 Mechanical interaction buffer/canister

5.3d SCC (buffer on copper canister)
3.7.6 Stress corrosion cracking, copper canister

5.3e Porewater pressure (hydrostatic pressure) (buffer on copper canister)
3.6.3 Deformation of copper canister from external pressure
4.6.3 Mechanical interaction buffer/canister

5.4 Buffer intrusion (buffer on voids in canister)
4.6.3 Mechanical interaction buffer/canister

5.6 Swelling pressure (buffer on backfill)
4.6.2 Mechanical interaction buffer/backfill

5.7 Intrusion (buffer on near-field rock)
4.6.1 Swelling
4.7.7 Colloid release/erosion

5.8 Mechanical impact (buffer on construction materials)
Not included in the Process Report

5.9a Colloid source (buffer on water composition in near-field rock)
4.7.7 Colloid release/erosion

5.9b Dissolution/precipitation (buffer on water composition in near-field)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

5.9c Ion-exchange/sorption (buffer on near-field water composition)
4.7.4 Ion exchange/sorption

5.9d Diffusion (buffer on near-field water composition)
4.7.3 Diffusion

5.9e Colloid filter (buffer on porewater composition)
4.8.3 Colloid transport

5.9f Water activcity (buffer on buffer porewater)
4.6.1 Swelling
4.7.10 Microbial processes
4.7.4 Ion exchange/sorption

5.9g Solubility (buffer on composition of buffer porewater)
4.5.3 Gas transport/dissolution
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

5.10a Intersects flow paths (buffer on water flow in near-field rock)
Initial state and affects initial state for the safety analysis

5.10b Flow in buffer (buffer on water flow in buffer)
4.5.1 Water transport under unsaturated conditions
4.5.2 Water transport under saturated conditions

5.10c Water exchange, canister (buffer on water flow through canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation
4.5.1 Water transport under unsaturated conditions
4.5.2 Water transport under saturated conditions

5.11 Gas flow in buffer (buffer properties on gas in buffer)
4.5.3 Gas transport/dissolution

5.12 Heat transport (buffer on temperature in canister and buffer)
4.4.1 Heat transport

5.13a Swelling pressure (buffer on near-field rock stresses)
4.6.4 Mechanical interaction buffer/near-field rock

5.13b Porewater pressure (buffer on near-field rock stresses)
4.6.6 Thermal expansion

5.14a Ion-exchange, sorption (buffer on radionuclides in buffer porewater)
4.8.5 Sorption

5.14b Diffusion (buffer on radionuclides in near-field water)
4.8.6 Diffusion

5.14c Colloid filter (buffer on radionuclides in near-field water outside the buffer)
4.8.3 Colloid transport

5.14d Solubility (buffer on radionuclides in buffer porewater)
4.8.4 Speciation of radionuclides

5.14e Dissolution (buffer on radionuclides in buffer porewater)
Not included in the Process Report

6.5 Confinement (backfill on buffer)
4.6.2 Mechanical interaction buffer/backfill

6.7 Intrusion (backfill on near-field rock)
Not included in the Process Report

6.8 Mechanical impact (backfill on construction materials)
Not included in the Process Report

6.9a Colloid source (backfill on near-field water composition)
4.7.7 Colloid release/erosion

6.9b Dissolution/precipitation (backfill on near-field water composition)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

6.9c Ion-exchange/sorption (backfill on backfill water composition)
4.7.4 Ion exchange/sorption

6.9d Diffusion (backfill on near-field water composition)
4.7.3 Diffusion

6.9e Colloid filter (backfill on near-field water composition)
Not included in the Process Report

6.10 Local hydrology (backfill on near-field water flow)
4.5.2 Water transport under saturated conditions

6.11 Gas flow (backfill on near-field gas)
4.5.3 Gas transport/dissolution

6.12 Heat transport (backfill on near-field temperature)
4.4.1 Heat transport

6.13a Swelling pressure (backfill on near-field rock stresses)
4.6.5 Mechanical interaction backfill/near-field rock

6.13b Tunnel dimensions (backfill on near-field rock stresses)
Initial state and affects initial state for the safety analysis

6.14a Ion-exchange, sorption (backfill on radionuclides in near-field water)
4.8.5 Sorption

6.14b Diffusion (backfill on radionuclides in near-field water)
4.8.6 Diffusion

6.14c Colloid filter (backfill on radionuclides in near-field water)
4.8.3 Colloid transport

6.14d Dissolution (backfill on radionuclides in backfill water)
Not included in the Process Report

7.5a Rock displacement (near-field rock on buffer)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

7.5b Confinement (near-field rock on buffer)
4.6.1 Swelling
4.6.4 Mechanical interaction buffer/near-field rock

7.5c Density decrease (near-field rock on buffer)
4.6.1 Swelling
4.7.7 Colloid release/erosion

7.6a Rock movements (near-field rock on backfill)
4.6.5 Mechanical interaction backfill/near-field rock

7.6b Confinement (near-field rock on backfill)
4.6.5 Mechanical interaction backfill/near-field rock

7.6c Density decrease (near-field rock on backfill)
4.7.7 Colloid release/erosion

7.8 Reinforcements (near-field rock on construction materials)
Not included in the Process Report

7.9a Sorption (near-field rock on water composition in near-field rock)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.9b Matrix diffusion (near-field rock on water composition in near-field rock)
5.7.3 Diffusion

7.9c Dissolution/precipitation (near-field rock on water composition in near-field rock)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

7.9d Earth currents (near-field rock on near-field water composition)
Not included in the Process Report

7.9e Molecular diffusion (near-field rock on water composition in near-field rock)
5.7.3 Diffusion

7.10 Local hydrology (near-field rock on near-field water flow)
5.5.1 Groundwater flow

7.11 Gas flow (near-field rock on near-field gas)
5.5.2 Gas flow/dissolution

7.12 Heat transport (near-field rock on near-field temperature)
5.4.1 Heat transport

7.13 Stress relaxation (near-field rock on near-field rock stresses)
5.6.3 Thermal movement

7.14a Fracture sorption (near-field rock on radionuclides in near-field water)
5.8.2 Sorption

7.14b Matrix diffusion (near-field rock on radionuclides in near-field water)
5.8.3 Molecular diffusion and matrix diffusion

7.14c Matrix sorption (near-field rock on radionuclides in near-field water)
5.8.2 Sorption

7.14d Molecular diffusion (near-field rock on radionuclides in near-field water)
5.8.3 Molecular diffusion and matrix diffusion

7.14e Dissolution (near-field rock on radionuclides in near-field water)
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.8.2 Sorption

8.3 Mechanical impact (construction materials on copper canister)
Not included in the Process Report

8.5 Confinement (construction materials on buffer)
Not included in the Process Report

8.6 Confinement (construction materials on backfill)
Not included in the Process Report

8.7 Mechanical support (rock reinforcements on near-field rock)
Not included in the Process Report

8.9a Alteration (construction materials on near-field water composition)
5.7.7 Decomposition of inorganic engineering material

8.9b Stray materials (construction materials on near-field water composition)
5.7.6 Microbial processes

8.10 Flow pattern (construction materials on near-field water flow)
Not included in the Process Report

8.11a Corrosion gases (construction materials on near-field gas)
5.7.7 Decomposition of inorganic engineering material

8.11b Gas inclusion (construction materials on near-field gas)
Not included in the Process Report

8.12 Heat transport (construction materials on near-field temperature)
Not included in the Process Report

8.14a Sorption/desorption (construction materials on radionucl. in near-field water)
Not included in the Process Report

8.14b Diffusion (construction materials on radionuclides in near-field water)
Not included in the Process Report

8.14c Dissolution (construction materials on radionuclides in near-field water)
Not included in the Process Report

9.1a Fuel alteration (water composition in canister on fuel matrix)
2.7.5 Fuel dissolution

9.1b Fuel dissolution/precipitation (water composition in canister on fuel)
2.7.5 Fuel dissolution

9.1c Cladding corrosion (water composition in canister on fuel cladding)
2.7.4 Metal corrosion

9.2 Corrosion (water composition in canister on steel canister)
3.7.1 Corrosion of cast iron insert

9.3 Corrosion (composition of buffer porewater on copper canister)
3.7.5 Corrosion of copper canister

9.5a Ion-exchange/sorption (composition of buffer porewater on buffer)
4.7.4 Ion exchange/sorption

9.5b Dissolution/precipitation (composition of buffer porewater on buffer)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

9.5c Microstructural constitution (composition of buffer porewater on buffer)
4.6.1 Swelling
4.7.4 Ion exchange/sorption

9.5d Illitization (composition of buffer porewater on buffer)
4.7.5 Montmorillonite transformation

9.6a Ion exchange/sorption (composition of backfill water on backfill)
4.7.4 Ion exchange/sorption

9.6b Dissolution/precipitation (composition of backfill water on backfill)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

9.6c Swelling (composition of backfill water on backfill)
4.6.1 Swelling
4.7.4 Ion exchange/sorption

9.7a Fracture alteration (near-field water composition on near-field rock)
5.7.5 Dissolution/precipitation of fracture-filling minerals

9.7b Rock alteration (near-field water composition on near-field rock)
5.7.4 Reactions groundwater/rock matrix

9.8a Dissolution/corrosion (near-field water composition on construction materials)
5.7.7 Decomposition of inorganic engineering material

9.8b Maturation (near-field water composition on construction materials)
Not included in the Process Report

9.10 Density, viscosity (near-field water composition on near-field water flow)
4.5.2 Water transport under saturated conditions
5.5.1 Groundwater flow

9.11a Gas dissolution (near-field water composition on near-field gas)
4.5.3 Gas transport/dissolution
5.7.9 Gas formation/dissolution

9.11b Microbial activity (near-field water composition on near-field gas)
4.7.10 Microbial processes
5.7.6 Microbial processes

9.11c Chemical reactions (near-field water composition on near-field gas)
5.7.5 Dissolution/precipitation of fracture-filling minerals

9.12 Heat transport (near-field water composition on near-field temperature)
2.4.1 Heat transport
4.4.1 Heat transport
5.4.1 Heat transport

9.14a Dissolution/precipitation (near-field wat. comp on radionucl. in near-field water)
2.7.8 Speciation of radionuclides, colloid formation
4.8.4 Speciation of radionuclides
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.8.2 Sorption

9.14b Sorption/desorption (near-field water comp. on radionucl. in near-field water)
2.8 Radionuclide transport
4.8.5 Sorption
5.8.2 Sorption

9.14c Colloid transport (near-field water comp. on radionucl. in near-field water)
2.8 Radionuclide transport
4.8.3 Colloid transport
5.8.4 Colloid transport

9.14d Dissolution of radioactive gas (n-f wat. comp. on radionucl. in near-field water)
5.8.6 Transport in gas phase

09.15 Exchange (near-field water comp. on far-field water comp.)
5.7.2 Advection/mixing

10.4 Intrusion/expulsion
2.5.1 Water and gas transport in canister cavity, boiling/condensation

10.5a Pressure (near-field water flow on buffer)
4.5.2 Water transport under saturated conditions

10.5b Erosion (near-field water flow on buffer)
4.7.7 Colloid release/erosion

10.6a Erosion (near-field water flow on backfill)
4.7.7 Colloid release/erosion

10.6b Solubility (near-field water flow on backfill)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

10.7a Erosion/sedimentation (near-field water flow on near-field rock)
Not included in the Process Report

10.7b Solubility (near-field water flow on near-field rock)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

10.8a Erosion (near-field water flow on construction materials)
Not included in the Process Report

10.8b Solubility (near-field water flow on construction materials)
Not included in the Process Report

10.8c Grouting (near-field water flow on construction materials)
Initial state and affects initial state for the safety analysis

10.9a Transport of species (near-field water flow on near-field water composition)
2.7.1 Advection and diffusion
4.7.2 Advection
5.7.2 Advection/mixing

10.9b Solubility (near-field water flow on near-field water composition)
4.5.3 Gas transport/dissolution
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.9 Gas formation/dissolution

10.11a Pressure (near-field water flow on near-field gas)
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution

10.11b Gas dissolution (near-field water flow on near-field gas)
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution
5.7.9 Gas formation/dissolution

10.11c Two-phase flow (near-field water flow on near-field gas)
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution

10.12 Heat convection (near-field water flow on near-field temperature)
4.4.1 Heat transport
5.4.1 Heat transport

10.13 Effective stress (near-field water flow on near-field rock stresses)
5.6.4 Reactivation-movement along existing fractures

10.14a Transport of dissolved RN (n-f water flow on radionucl. in near-field water)
2.8 Radionuclide transport
4.8.2 Advection
5.8.1 Advection and dispersion

10.14b Transport of dissolved gas (n-f water flow on radionucl. in near-field water)
5.5.2 Gas flow/dissolution
5.8.6 Transport in gas phase

10.14c Solubility (near-field water flow on radionuclides in near-field water)
Not included in the Process Report

10.15 Hydraulic gradient (near-field water flow on far-field water flow)
5.5.1 Groundwater flow

11.1a Cladding corrosion (gas in canister on fuel)
2.7.4 Metal corrosion

11.1b H2 catalysis (gas in canister on fuel)
Not included in the Process Report

11.2a Corrosion by nitrous gases (gas in canister on steel canister)
3.7.3 Stress corrosion cracking of cast iron insert

11.2b Corrosion by water vapour (gas in canister on steel canister)
3.7.1 Corrosion of cast iron insert

11.2c Hydrogen pressure (gas in canister on steel canister)
3.7.1 Corrosion of cast iron insert

11.2d Internal impact (gas in canister on steel canister)
3.6.2 Deformation of cast iron insert

11.2e External impact (gas outside steel canister on steel canister)
4.6.3 Mechanical interaction buffer/canister

11.3a Corrosion (near-field gas on copper canister)
3.7.5 Corrosion of copper canister
3.7.6 Stress corrosion cracking, copper canister

11.3b Internal impact (gas in canister on copper canister)
3.6.2 Deformation of cast iron insert

11.5a Piping (gas in buffer on buffer)
4.5.3 Gas transport/dissolution

11.5b Flotation (gas in buffer on buffer)
4.5.3 Gas transport/dissolution

11.5c Porewater pressure (gas inside buffer on buffer)
Not included in the Process Report

11.5d Dehydration (gas inside buffer on buffer)
4.5.3 Gas transport/dissolution

11.5e Chemical reactions (gas in buffer on buffer)
Not included in the Process Report

11.6a Dehydration (gas in backfill on backfill)
4.5.1 Water transport under unsaturated conditions

11.6b Piping (gas in backfill on backfill)
4.5.3 Gas transport/dissolution

11.7a Dehydration (gas in near-field rock on near-field rock)
5.5.2 Gas flow/dissolution

11.7b Chemical reactions (gas in near-field rock on near-field rock)
Not included in the Process Report

11.7c Fractures (gas in near-field rock on near-field rock)
5.5.2 Gas flow/dissolution

11.8 Mechanical impact (near-field gas on construction materials)
Not included in the Process Report

11.9a Gas dissolution (near-field gas on near-field water composition)
4.5.3 Gas transport/dissolution
5.7.9 Gas formation/dissolution

11.9b Radiolysis (gas in canister on water composition in canister)
2.7.3 Water radiolysis

11.10a Displacement (near-field gas on near-field water flow)
2.5.1 Water and gas transport in canister cavity, boiling/condensation
4.5.3 Gas transport/dissolution

11.10b Two-phase flow (near-field gas on near-field water flow)
5.5.2 Gas flow/dissolution

11.12 Heat transport (near-field gas on near-field temperature)
2.4.1 Heat transport
4.4.1 Heat transport
5.4.1 Heat transport

11.14a Colloids on gas bubbles (near-field gas on radionuclides in near-field water)
5.8.6 Transport in gas phase

11.14b Dissolution of radioactive gas (near-field gas on radionucl. in n-f water)
5.8.6 Transport in gas phase

11.15a Gas flow (near-field gas on far-field gas)
5.5.2 Gas flow/dissolution

11.15b Composition (near-field gas on far-field gas)
5.5.2 Gas flow/dissolution

11.15c Radioactive gas (near-field gas on far-field gas)
5.8.6 Transport in gas phase

12.1a Structural/chemical alteration (temperature in canister on fuel)
Not included in the Process Report

12.1b Kinetics (temperature in canister on fuel)
2.7.4 Metal corrosion
2.7.5 Fuel dissolution

12.1c Equilibria (near-field temperature on fuel)
2.7.7 Speciation of iron corrosion products
2.7.8 Speciation of radionuclides, colloid formation

12.1d Volatility and migration (temperature in canister on fuel)
Not included in the Process Report

12.1e Expansion/contraction (temperature in canister on fuel cladding)
Not included in the Process Report

12.2a Expansion/contraction (temperature in canister on steel canister)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

12.2b Mechanical strength (temperature in canister on steel canister)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

12.2c Kinetics (temperature in canister on steel canister)
3.7.1 Corrosion of cast iron insert

12.2d Equlibria (temperature in canister on steel canister)
2.7.7 Speciation of iron corrosion products

12.3a Expansion/contraction (temperature in canister on copper canister)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

12.3b Mechanical strength (temperature in canister on copper canister)
3.6.4 Thermal expansion (both cast iron insert and copper canister)

12.3c Kinetics (temperature in canister on copper canister)
3.7.5 Corrosion of copper canister

12.3d Equlibria (temperature in canister on copper canister)
3.7.5 Corrosion of copper canister

12.4 Phase changes (temperature in canister on voids in canister)
2.5.1 Water and gas transport in canister cavity, boiling/condensation

12.5a Kinetics (temperature in buffer on buffer)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

12.5b Equlibria (temperature in buffer on buffer)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

12.5c Hydraulic conductivity (temperature in buffer on buffer)
4.5.2 Water transport under saturated conditions

12.5d Swelling pressure (temperature in buffer on buffer)
4.6.6 Thermal expansion

12.5e Expansion/contraction (temperature in buffer on buffer)
4.6.6 Thermal expansion

12.5f Porewater pressure (temperature in buffer on buffer)
4.6.6 Thermal expansion

12.5g Thermal properties (tmperature in buffer on buffer)
4.4.1 Heat transport

12.5h Shear strength (temperature in buffer on buffer)
4.6.6 Thermal expansion

12.6a Kinetics (temperature in backfill on backfill)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

12.6b Equilibria (temperature in backfill on backfill)
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

12.6c Hydraulic conductivity (temperature in buffer on buffer)
4.5.2 Water transport under saturated conditions

12.7a Fracturing (temperature in near-field rock on near-field rock)
5.6.3 Thermal movement
5.6.5 Fracturing

12.7b Fracture aperture (temperature in near-field rock on near-field rock)
5.6.3 Thermal movement
5.6.4 Reactivation-movement along existing fractures

12.7c Kinetics (temperature in near-field rock on near-field rock)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

12.7d Equlibria (temperature in near-field rock on near-field rock)
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals

12.7e Thermal conductivity (temperature in near-field rock on near-field rock)
5.4.1 Heat transport

12.8a Expansion/contraction (near-field temperature on construction materials)
Not included in the Process Report

12.8b Kinetics (near-field temperature on construction materials)
Not included in the Process Report

12.8c Equilibria (near-field temperature on construction materials)
Not included in the Process Report

12.9a Kinetics (near-field temperature on near-field water composition)
2.7.4 Metal corrosion
2.7.5 Fuel dissolution
3.7.1 Corrosion of cast iron insert
3.7.5 Corrosion of copper canister
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.7 Decomposition of inorganic engineering material

12.9b Equilibria (near-field temperature on near-field water composition)
2.7.5 Fuel dissolution
2.7.7 Speciation of iron corrosion products
2.7.8 Speciation of radionuclides, colloid formation
3.7.5 Corrosion of copper canister
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities
5.7.4 Reactions groundwater/rock matrix
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.7 Decomposition of inorganic engineering material

12.9c Phase changes (near-field temperature on near-field water comp.)
Not included in the Process Report

12.9d Diffusion (near-field temperature on near-field water composition)
2.7.1 Advection and diffusion
4.7.3 Diffusion
5.7.3 Diffusion

12.9e Gradient transport (near-field temperature on near-field water comp.)
Not included in the Process Report

12.10a Convection cells (near-field temperature on near-field water flow)
4.5.1 Water transport under unsaturated conditions
4.5.2 Water transport under saturated conditions
5.5.1 Groundwater flow

12.10b Viscosity (near-field temperature on near-field water flow)
4.5.2 Water transport under saturated conditions
5.5.1 Groundwater flow

12.11a Expansion/compression (near-field temperature on near-field gas)
2.6.1 Thermal expansion/cladding failure

12.11b Gas dissolution (near-field temperature on near-field gas)
4.5.1 Water transport under unsaturated conditions
4.5.3 Gas transport/dissolution
5.5.2 Gas flow/dissolution
5.7.9 Gas formation/dissolution

12.14a Kinetics (near-field temperature on radionuclides in near-field water)
2.7.4 Metal corrosion
2.7.5 Fuel dissolution
4.8.5 Sorption
5.8.2 Sorption

12.14b Equilibria (near-field temperature on radionuclides in near-field water)
2.7.8 Speciation of radionuclides, colloid formation
4.8.4 Speciation of radionuclides
5.8.5 Speciation

12.14c Diffusion (near-field temperature on radionuclides in near-field water)
2.8 Radionuclide transport
4.8.6 Diffusion
5.8.3 Molecular diffusion and matrix diffusion

12.14d Gradient transport (near-field temperature on radionuclides in n-f water)
Not included in the Process Report

12.15 Heat transfer (near-field temperature on far-field temperature)
5.4.1 Heat transport

13.5a Rock displacement (near-field rock stresses on buffer)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.4 Reactivation-movement along existing fractures

13.5b Rock creep (near-field rock stresses on buffer)
4.6.4 Mechanical interaction buffer/near-field rock
5.6.6 Time-dependent deformations

13.6a Rock displacement (near-field rock stresses on backfill)
4.6.5 Mechanical interaction backfill/near-field rock
5.6.4 Reactivation-movement along existing fractures

13.6b Rock creep (near-field rock stresses on backfill)
4.6.5 Mechanical interaction backfill/near-field rock
5.6.6 Time-dependent deformations

13.7a Fracturing (near-field rock stresses on near-field rock)
5.6.5 Fracturing
5.6.6 Time-dependent deformations

13.7b Fracture aperture (near-field rock stresses on near-field rock)
5.6.4 Reactivation-movement along existing fractures
5.6.6 Time-dependent deformations

13.8 Deformations (near-field rock stresses on construction materials)
Not included in the Process Report

13.15 Stress (near-field rock stresses on far-field rock stresses)
Not included in the Process Report

14.1 Dissolution/precipitation (radionuclides in water in canister on fuel)
2.7.8 Speciation of radionuclides, colloid formation

14.2 Contamination (radionuclides in water in canister on steel canister)
2.8 Radionuclide transport

14.3 Contamination (radionuclides in near-field water on copper canister)
2.8 Radionuclide transport

14.5a Contamination (radionuclides in buffer porewater on buffer)
4.8.5 Sorption

14.5b Radiation effects (radionuclides in buffer porewater on buffer)
4.7.8 Radiation-induced montmorillonite transformation

14.6a Contamination (radionuclides in backfill water on backfill)
4.8.5 Sorption

14.6b Radiation effects (radionuclides in backfill water on backfill)
4.7.8 Radiation-induced montmorillonite transformation

14.7a Contamination (radionuclides in water in near-field rock on near-field rock)
5.8.2 Sorption

14.7b Radiation effects (radionuclides in water in near-field rock on near-field rock)
Not included in the Process Report

14.8a Contamination (radionuclides in near-field water on construction materials)
Not included in the Process Report

14.8b Radiation effects (radionuclides in near-field water on construction materials)
Not included in the Process Report

14.9a Contamination (radionuclides in near-field water on near-field water comp.)
Not included in the Process Report

14.9b Redox front (radionuclides in near-field water on near-field water comp.)
2.7.5 Fuel dissolution

14.9c Radiolysis (radionuclides in near-field water on near-field water composition)
Not included in the Process Report

14.11 Dissolution/evaporation (radionuclides in near-field water on near-field gas)
5.8.6 Transport in gas phase

14.12 Decay heat (radionuclides in near-field water on near-field temperature)
Not included in the Process Report

14.15 Source term (radionuclides in near-field water on radionuclides in far-field)
5.8.1 Advection and dispersion

15.9a Earth currents (far-field rock prop on near-field water comp.)
Not included in the Process Report

15.9b Exchange (far-field water comp. on near-field water comp)
5.7.2 Advection/mixing

15.10 Regional flow (far-field GW flow on near-field water flow)
5.5.1 Groundwater flow

15.11a Gas flow (far-field gas on near-field gas)
5.5.2 Gas flow/dissolution

15.11b Composition (far-field gas on near-field gas)
Not included in the Process Report

15.12 Heat exchange (far-field temp. on near-field temp.)
5.4.1 Heat transport

15.13 Stress (far-field stress on near-field stress)
5.6.2 Movements in intact rock
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing
5.6.6 Time-dependent deformations

15.14 Natural radionuclides (RN in far-field water on RN in near-field water)
Not included in the Process Report

Coupling of the far-field interactions to the headings in the Process Report.

The diagonal elements and the interactions with priority =0 are not listed

1.2 Excavation method
Initial state and affects initial state for the safety analysis
4.6.5 Mechanical interaction backfill/near-field rock

1.3a Excavation method
Initial state and affects initial state for the safety analysis

1.3b Grouting
Not included in the Process Report

1.3c Reinforcement
Not included in the Process Report

1.5 Displacement effects
Initial state and affects initial state for the safety analysis

1.6a Construction materials
5.7.7 Decomposition of inorganic engineering material

1.6b Stray materials
5.7.6 Microbial processes

1.8 Drawdown effects
Initial state and affects initial state for the safety analysis

1.9a Repository depth
Initial state and affects initial state for the safety analysis

1.9b Ventilation
Initial state and affects initial state for the safety analysis

1.10 Tunnel dimensions
Initial state and affects initial state for the safety analysis

1.11a Ventilation
Initial state and affects initial state for the safety analysis

1.11b Blasting gas
Initial state and affects initial state for the safety analysis

1.11c Gas source
5.7.7 Decomposition of inorganic engineering material

1.13a Industrial facility
Not included in the Process Report

1.13b Dumps
Not included in the Process Report

2.1a Swelling ability
Initial state and affects initial state for the safety analysis

2.1b Heat
Initial state and affects initial state for the safety analysis

2.3 Buffer/backfill penetration into EDZ
4.6.1 Swelling
4.7.7 Colloid release/erosion

2.5 Buffer into intersecting fractures
4.6.1 Swelling
4.7.7 Colloid release/erosion

2.6a Colloid source
4.7.7 Colloid release/erosion

2.6b Groundwater composition
5.7.2 Advection/mixing

2.7a Changed flow around holes
Initial state and affects initial state for the safety analysis

2.7b Changed flow in tunnels
4.5.2 Water transport under saturated conditions

2.8 Resaturation
5.5.1 Groundwater flow

2.9 Heat generation
4.4.1 Heat transport

2.10 Swelling pressure
4.6.4 Mechanical interaction buffer/near-field rock
4.6.5 Mechanical interaction backfill/near-field rock

2.11 Gas source
4.5.3 Gas transport/dissolution

2.12 Source term
5.7.2 Advection/mixing
5.8.1 Advection and dispersion

3.1a Excavation method
Initial state and affects initial state for the safety analysis

3.1b Amount of reinforcement
Initial state and affects initial state for the safety analysis

3.2a Volume for buffer/backfill swelling
4.7.7 Colloid release/erosion

3.2b Rock fallout
4.6.4 Mechanical interaction buffer/near-field rock
4.6.5 Mechanical interaction backfill/near-field rock

3.6a Changed porosity and surface area
Not included in the Process Report

3.6b Colloid and particulate generation
5.7.8 Colloid formation

3.7 Changed permeability
5.5.1 Groundwater flow

3.9 Modified thermal diffusivity
5.4.1 Heat transport

3.10 Fractures affected
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

3.11a Indiffusion of air
Initial state and affects initial state for the safety analysis

3.11b Transport path for gas
5.5.2 Gas flow/dissolution

3.12a Changed porosity and surface area
5.8.2 Sorption
5.8.3 Molecular diffusion and matrix diffusion

3.12b Sorption capacity
5.8.2 Sorption

4.1 Layout/construction method
Initial state and affects initial state for the safety analysis

4.3 Magnitude and geometrical extent
Initial state and affects initial state for the safety analysis

4.5 Fracture characteristics and infilling mineralisation
Initial state and affects initial state for the safety analysis

4.6 Rock-water interaction
5.7.4 Reactions groundwater/rock matrix
5.7.8 Colloid formation

4.7a Matrix conductivity
5.5.1 Groundwater flow

4.7b Rock compressibility
5.6.2 Movements in intact rock

4.9 Thermal properties
5.4.1 Heat transport

4.10 Genesis, tectonic history and rock type
Initial state and affects initial state for the safety analysis

4.11 Radon generation
Not included in the Process Report

4.12a Sorption
5.8.2 Sorption

4.12b Matrix diffusion
5.8.3 Molecular diffusion and matrix diffusion

4.13a Land use
Not included in the Process Report

4.13b Potential human intrusion
Not included in the Process Report

5.1a Avoid major fracture zones
Initial state and affects initial state for the safety analysis

5.1b Constructability
Initial state and affects initial state for the safety analysis

5.3 Mechanical properties and fracture frequency
Initial state and affects initial state for the safety analysis

5.6a Dissolution of fracture minerals
5.7.5 Dissolution/precipitation of fracture-filling minerals

5.6b Colloid generation
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.8 Colloid formation

5.7a Flow paths
5.5.1 Groundwater flow

5.7b Connectivity
5.5.1 Groundwater flow

5.7c Fracture aperture
5.5.1 Groundwater flow

5.7d Storage capacity
5.5.1 Groundwater flow

5.9 Thermal properties
5.4.1 Heat transport

5.10 Stress magnitude and orientation
Not included in the Process Report

5.11 Transport path for gas
5.5.2 Gas flow/dissolution

5.12a Molecular diffusion
5.8.3 Molecular diffusion and matrix diffusion

5.12b Surface area
5.8.2 Sorption
5.8.3 Molecular diffusion and matrix diffusion

5.12c Sorption
5.8.2 Sorption

5.13 Wells
5.5.1 Groundwater flow

6.1a Depth affected by redox potential
Initial state and affects initial state for the safety analysis

6.1b Construction materials
Initial state and affects initial state for the safety analysis

6.2 TDS - ion exchange - illitisation
4.7.4 Ion exchange/sorption
4.7.5 Montmorillonite transformation
4.7.6 Dissolution/precipitation of impurities

6.3a Precipitation/bacterial growth operating phase
Initial state and affects initial state for the safety analysis
5.7.6 Microbial processes

6.3b Precipitation/bacterial growth in the long run
5.7.5 Dissolution/precipitation of fracture-filling minerals
5.7.6 Microbial processes

6.4 Groundwater rock interaction
5.7.4 Reactions groundwater/rock matrix

6.5 Precipitation and dissolution of fracture minerals
5.7.5 Dissolution/precipitation of fracture-filling minerals

6.7 Density and viscosity
5.5.1 Groundwater flow

6.8 Density affects groundwater head
5.5.1 Groundwater flow

6.9 Heat conductivity
Not included in the Process Report

6.11a Chemically generated gas
5.7.5 Dissolution/precipitation of fracture-filling minerals

6.11b Microbially generated gas
5.7.6 Microbial processes

6.11c Clathrates
5.7.10 Methane ice formation

6.12a Sorption and solubility
5.8.3 Molecular diffusion and matrix diffusion
5.8.5 Speciation

6.12b Colloids and bacteria
5.8.4 Colloid transport

6.13a Water use
Not included in the Process Report

6.13b Biotopes
Not included in the Process Report

7.1a Canister positioning
Initial state and affects initial state for the safety analysis

7.1b Construction methods
Initial state and affects initial state for the safety analysis

7.2a Saturation
4.5.1 Water transport under unsaturated conditions

7.2b Bentonite erosion
4.7.7 Colloid release/erosion

7.3 Erosion
Not included in the Process Report

7.5 Erosion and sedimentation
Not included in the Process Report

7.6 Mixing
5.7.2 Advection/mixing

7.8 Equalisation of pressures
5.5.1 Groundwater flow

7.9 Forced heat convection
5.4.1 Heat transport

7.11 Two-phase flow
5.5.1 Groundwater flow
5.5.2 Gas flow/dissolution

7.12a Transport of dissolved gas
5.8.6 Transport in gas phase

7.12b Direction, distribution and magnitude
5.8.1 Advection and dispersion
5.8.4 Colloid transport

7.12c Hydrodynamic dispersion
5.8.1 Advection and dispersion

7.13 Recharge and discharge
5.5.1 Groundwater flow

8.1 Construction methods
Initial state and affects initial state for the safety analysis

8.6 Solubility
Not included in the Process Report

8.7 Driving force due to pressure gradient
5.5.1 Groundwater flow

8.10 Effective stress
5.6.4 Reactivation-movement along existing fractures

8.11a Gas solubility
5.7.9 Gas formation/dissolution

8.11b Gas law
5.5.2 Gas flow/dissolution

8.13 Potential effect on vegetation
Not included in the Process Report

9.2 Temperature in buffer/backfill
4.4.1 Heat transport
5.4.1 Heat transport

9.4a Thermal expansion
5.6.3 Thermal movement

9.4b Thermal conductivity
5.4.1 Heat transport

9.5 Permafrost
5.5.1 Groundwater flow

9.6 Dissolution and precipitation of minerals
5.7.5 Dissolution/precipitation of fracture-filling minerals

9.7 Viscosity
5.5.1 Groundwater flow

9.8 Density
5.5.1 Groundwater flow

9.10 Thermal expansion
5.6.3 Thermal movement

9.11a Gas solubility
5.7.9 Gas formation/dissolution

9.11b Gas law
5.5.2 Gas flow/dissolution

9.12 Kinetic effects
5.8.2 Sorption
5.8.3 Molecular diffusion and matrix diffusion

10.1a Design/layout
Initial state and affects initial state for the safety analysis

10.1b Construction methods
Initial state and affects initial state for the safety analysis

10.2a Reaction force on swelling pressure
4.6.1 Swelling
4.6.4 Mechanical interaction buffer/near-field rock
4.6.5 Mechanical interaction backfill/near-field rock

10.2b Rock fallout
4.6.4 Mechanical interaction buffer/near-field rock
4.6.5 Mechanical interaction backfill/near-field rock
5.6.6 Time-dependent deformations

10.3a Mechanical stability
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing
5.6.6 Time-dependent deformations

10.3b Fracture aperture
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing
5.6.6 Time-dependent deformations

10.4 Mechanical stability
5.6.5 Fracturing

10.5a Mechanical stability
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

10.5b Fracture aperture
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

10.8 Confined aquifers
Not included in the Process Report

10.13 Mechanical stability
Not included in the Process Report

11.1 Ventilation problems
Initial state and affects initial state for the safety analysis

11.3a Opening of fractures
5.5.2 Gas flow/dissolution

11.3b Heat conduction
5.4.1 Heat transport

11.4a Fracturing
5.5.2 Gas flow/dissolution

11.4b Thermal properties
5.4.1 Heat transport

11.5 Fracture aperture
5.5.2 Gas flow/dissolution

11.6a pH and Eh affected
5.7.6 Microbial processes
5.7.9 Gas formation/dissolution

11.6b Eh affected
5.7.6 Microbial processes
5.7.9 Gas formation/dissolution

11.7 Creation of two-phase flow conditions
5.5.1 Groundwater flow
5.5.2 Gas flow/dissolution

11.8 Capillary forces
5.5.1 Groundwater flow
5.5.2 Gas flow/dissolution

11.9 Gas law
Not included in the Process Report

11.12 Colloid sorption on gas bubbles
5.8.6 Transport in gas phase

11.13 Gas release
5.8.6 Transport in gas phase

12.1 Design/layout
Initial state and affects initial state for the safety analysis

12.6a Radiolysis
Not included in the Process Report

12.6b Redox front
2.7.7 Speciation of iron corrosion products

12.13 Contamination
5.8.1 Advection and dispersion
5.8.3 Molecular diffusion and matrix diffusion
5.8.4 Colloid transport
5.8.6 Transport in gas phase

13.1 Siting - Design/Layout
Initial state and affects initial state for the safety analysis

13.6 Infiltrating water
5.7.2 Advection/mixing

13.7 Surface water recharge and percolation
5.5.1 Groundwater flow

13.8a Land use
5.5.1 Groundwater flow

13.8b Tidal driving forces
Not included in the Process Report

13.8c Climatic driving forces
5.5.1 Groundwater flow

13.8d Hydraulic gradients
5.5.1 Groundwater flow

13.9 Climatic driving forces
5.4.1 Heat transport

13.10a External load
5.6.4 Reactivation-movement along existing fractures
5.6.5 Fracturing

13.10b Erosion
Not included in the Process Report