Errata 2011-10

SKB TR-11-01

Long-term safety for the final repository for spent nuclear fuel at Forsmark

Main report of the SR-Site project

Volume I

In the earlier distributed report, there are errors that have now been corrected. The corrected pages 38, 67, 97, 111, 168, 186, 245, 246, 259 and 269 are enclosed. The changed text is marked with a vertical line in the page margin. An updated pdf version of the report, dated 2011-10, can be found at www.skb.se/publications.

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After about 10,000 years, the doses for all cases are below the dose caused by typical background radiation in Sweden, except the case where retention properties of canisters, buffer and rock are all disregarded (case D*) and that with rapid conversion of the waste form in combination with failed canisters (cases E and E*). The low flow and favourable groundwater chemistry of the rock and the presence of backfill and closure of repository tunnel thus provide substantial protection from a waste with unaltered conversion rate.

Additional results

Further results from the radionuclide and dose calculations are presented in the conclusions section below. These include a summation of risk contributions from scenarios which could not be ruled out from the assessment, the calculations of doses to non-human biota, calculations with alternative, simplified analytical models, and the use of alternative safety indicators.

S3.12 Step 10: Additional analyses and supporting arguments

Overview

In this step of the assessment, a number of additional analyses, required to complete the safety assessment, are carried out.

- Analyses of scenarios related to future human actions.
- Analyses required to demonstrate optimisation and use of best available technique, BAT.
- Verification that FEPs omitted in earlier parts of the assessment are of negligible significance in the light of the completed scenario and risk analysis.
- A brief account of the time period beyond one million years.
- Use of natural analogues.

Only results from the first point are given below. Results of the remaining points are summarised as appropriate in the conclusion section of this summary.

Scenarios related to future human actions

Based on generally accepted principles and SSM's Regulations, the future human actions considered are restricted to global pollution and actions that are carried out after the sealing of the repository, take place at or close to the repository site, are unintentional, and impair the safety functions of the repository's barriers. A systematic approach including a technical analysis, an analysis of societal factors, a choice of representative cases and, finally, scenario descriptions and consequence analysis of the chosen cases is adopted. The main conclusions of these analyses are summarised below.

- For a stylised case where a drilling team unintentionally penetrates a canister and part of spent fuel is brought to the surface, the following is found.
  - The dose rate that a member of the drilling personnel would be exposed to while working in the highly contaminated area can be quite high. However, if the drilling occurs at c. 5,000 years after repository closure, the dose rate will have decreased to a value below 1 mSv/hour.
  - The total dose from using the borehole in the drilling case as a well 300 years after repository closure is below background radiation.
  - The maximum total annual effective dose from agricultural use of soil contaminated by fuel debris is very high, but it is noted that there are a number of simplified, pessimistic assumptions made in the calculations.
- The impacts of an open investigation borehole on the groundwater flow and on the long-term properties of the backfill in the deposition tunnel in the vicinity of the borehole are assessed as negligible.
- A tunnel constructed in the upper part of the bedrock would not affect the groundwater flow at repository depth such that the presence of the tunnel violates the safety functions of the deep repository.
- Exploitation of the potential mineral resources in the vicinity of the Forsmark site would not impact the safety functions of the repository.

i) design premises derived from the SR-Can assessment, ii) the reference design selected to achieve the requirements, iii) verifying analyses that the reference design does fulfil the design premises, iv) the production and control procedures selected to achieve the reference design, v) verifying analyses that these procedures, if implemented, would achieve the reference design and vi) an account of the achieved initial state. The last point is the key input to the safety assessment. The initial state of the engineered components is described in Chapter 5, based on the contents of the **Production reports** relevant to long-term safety.

The FEP processing in step 2 resulted in a number of FEPs related to the initial state. Most of these are covered through the descriptions of the initial state and the subsequent use of this information in the assessment. A few initial state FEPs, relating for example to an incomplete closure of the repository require separate treatment in the scenario analysis in later stages of the assessment. Such FEPs are accounted for in Section 5.1.3.

2.5.3 Step 3: Description of external conditions

Factors related to external conditions are handled in the three categories "climate related issues", "large-scale geological processes and effects" and "future human actions", FHA. The handling of these factors is described in the **Climate report**, the **Geosphere process report**, and the **FHA report**, respectively.

A key point in the handling of external conditions is the establishment of reference external conditions for the subsequent analysis. These reference external conditions postulate a repetition of the last 120,000 year glacial cycle, the Weichselian. An alternative reference evolution is based on the assumption of a global warming effect. In addition, physically possible climate conditions that would have the most severe impact on repository safety are sought for use in the scenario analyses in a later step of the assessment. The handling of climate related issues is described in more detail in Section 6.2.

Future human actions are handled according to a methodology established in the SR-Can assessment with minor updates for SR-Site. Based on a structured account of a large number of FEPs relating to FHA, a selection of stylised cases for further analyses is made. This is described in the analysis of FHA scenarios, Section 14.2.

2.5.4 Step 4: Description of processes

The identification and handling of processes of importance for the long-term evolution and safety of the repository is a key element in the safety assessment. The identification of processes is based on earlier assessments and FEP screening. All identified processes within the system boundary relevant to the long-term evolution of the system are described in three dedicated **Process reports**, one for the fuel and canister, one for the buffer, backfill and repository closure and one for the geosphere. Short-term geosphere processes/alterations due to repository excavation are included in the **Geosphere process report** and are taken into account in the assessment.

Each process is documented in the **Process reports**, following a template with the following headings:

- Overview/general description.
- Dependencies between process and system variables.
- Boundary conditions.
- Model studies/experimental studies.
- Natural analogues/observations in nature.
- Time perspective in which the process is relevant.
- Handling in the safety assessment SR-Site.
- Handling of uncertainties in SR-Site.
- Adequacy of references supporting the handling in SR-Site.

In addition, there is a possibility to enter in the FEP catalogue any issue that is, for whatever reason, identified as relevant for the safety assessment. For SR-Can, some site-specific issues identified in the preliminary safety evaluation of the sites were included. For Forsmark these issues concerned the potential impact of nearby nuclear power plants and the power cable to Finland and the effect of a deep mine excavation near, but outside, the tectonic lens at Forsmark. For SR-Site, no additional issues that are not covered by FEPs already included in the SR-Site FEP catalogue have been identified.

In the following, each category is briefly described.

Initial state FEPs

This category describes deviations from the intended initial state as a consequence of undetected mishaps, sabotage, repository left open, etc. These are propagated to the selection of scenarios described in Chapter 11. The initial state FEPs in the SR-Site FEP catalogue are in essence the same as those in the SR-Can FEP catalogue. The only exception is that two initial state FEPs defined for backfill of other repository parts in the SR-Can catalogue, in the SR-Site catalogue are replaced by two initial state FEPs defined for the central area and two for the top seal.

It should be noted that the intended initial state with tolerances, the reference initial state, is one of the bases for the main scenario. The reference initial state for the different system components is described in the **Spent fuel report**, the **Canister-**, **Buffer-**, **Backfill-** and **Closure production reports** and in the **Underground openings construction report**, and summarised in Chapter 5. In the FEP catalogue, each variable record, see below, contains also a reference to the description of the reference initial state for that variable.

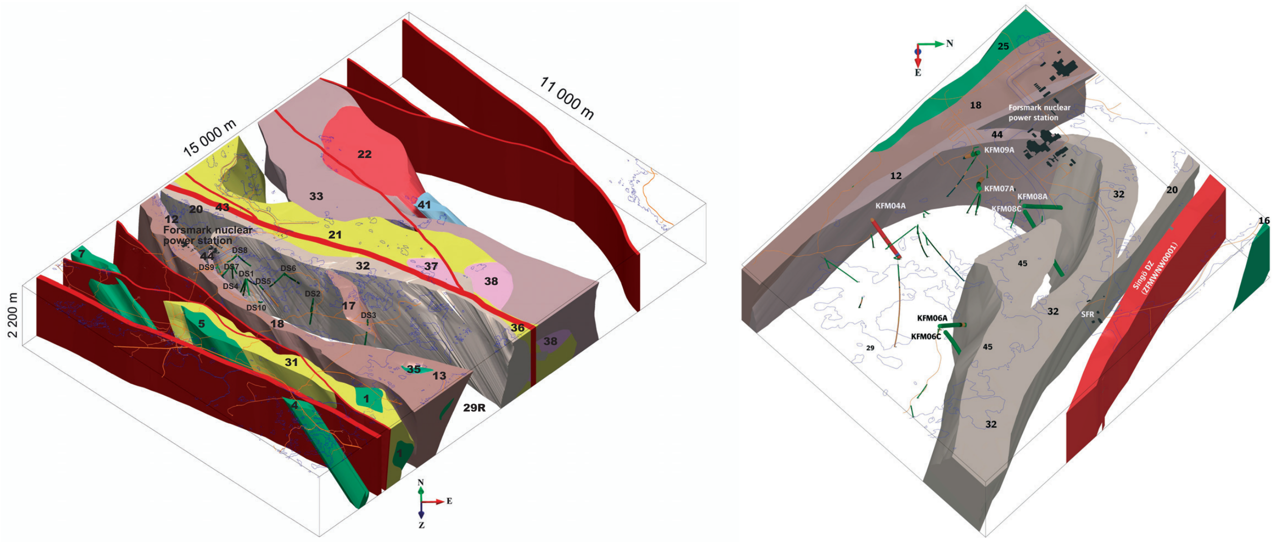
Processes

These FEPs are long-term processes relevant to repository safety for each of the system components fuel, canister, buffer, backfill, tunnel plug, central area, top seal, bottom plate in deposition holes, borehole seals and geosphere. All internal processes are comprehensively documented in a number of **Process reports**, see further Chapter 7. The handling of all processes in the fuel, canister, buffer, backfill and geosphere is summarised in process tables, given in Chapter 7. There are typically around 20 processes for each system component.

A few modifications in the list of internal processes for the system components fuel, canister, buffer, backfill and geosphere have been made compared to the list of processes included in SR-Can. These modifications were not initiated by the complementary mapping of new project FEPs in version 2.1 of the NEA FEP database, but have been made to improve the structure and logic of the descriptions. For example, to improve the handling of uncertainties in the geochemical evolution of the buffer, some mechanisms included in integrated descriptions in SR-Can are in SR-Site included as separate processes, e.g. iron-bentonite interactions and cementation. Another example concerns a modification in the list of geosphere processes. In SR-Can, surface erosion and weathering was described in the Geosphere process report /SKB 2006d/, but in SR-Site the description of these mechanisms is included in the **Climate report** and also addressed and considered in the biosphere analyses and reporting. For the system components not treated in detail in SR-Can, i.e. tunnel plugs, central area, top seal, bottom plate in deposition holes and borehole seals, process FEPs have been established largely based on the list of processes defined for the system components buffer and backfill. The outcome of the mapping in SR-Site of FEPs in the NEA FEP database was used to check that no relevant processes are missing in the set of processes for these system components.

Variables

These FEPs are the variables needed to describe the evolution of the state of the fuel, canister, buffer, backfill, tunnel plugs, central area, top seal, bottom plate in deposition holes, borehole seals and geosphere over time. They are thus essentially tables with definitions. The identification of variables has been done by the experts responsible for the documentation of the processes relevant for long-term safety. The sets of variables were established in conjunction with the documentation of the processes, since it had to be ensured that the variable sets were suited to describe all conceivable alterations of the barrier properties as a result of the long-term processes. There are typically around 10 variables



Regional deformation zone
Granite, fine- to medium-grained
Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
Aplitic granite, medium-grained granite and felsic volcanic rock, metamorphic and, in part, albitised
Granite to granodiorite, metamorphic, medium-grained
Tonalite and granodiorite, metamorphic
Diorite, quartz diorite, gabbro and ultramafic rock, metamorphic
Felsic to intermediate volcanic rock, metamorphic and, in part, albitised
Sedimentary rock, metamorphic, veined to migmatitic

Regional deformation zone
Aplitic granite, medium-grained granite and felsic volcanic rock, metamorphic and, in part, albitised
Granite to granodiorite, metamorphic, medium-grained
Tonalite and granodiorite, metamorphic
Diorite, quartz diorite, gabbro and ultramafic rock, metamorphic

Figure 4-8. *Three dimensional model for rock domains (numbered) and regional deformation zones (red colour). Several domains, including RFM029, are unshaded in order to display the structural style at the Forsmark site and in the tectonic lens. The dominant rock type in each domain is illustrated with the help of different colours (see legend). Left: Regional model showing the modelled, south-eastern elongation of several domains (Figure 4-15 in /Stephens et al. 2007/). Right: Rock domains in the target volume in the north-western part of the candidate area, viewed to the west from approximately the position of SFR (Figure 4-6 in /Stephens et al. 2007/).*

Rock domains outside the target volume

Rock domains outside the tectonic lens and target volume dip steeply towards the south-west, following the trend of the coastal deformation belt (Figure 4-8). They are dominated by different types of granitoid, predominantly felsic volcanic rocks and quartz-poor or quartz-deficient diorite to gabbro. More inhomogeneous bedrock is conspicuous in domains RFM018 and RFM021, on both sides of the tectonic lens (Figure 4-7).

Confidence

Confidence in both the geometry and properties of rock domains within and immediately around the target volume is high down to a depth of 1,000 m, whereas significant uncertainties remain concerning the character and geometry of rock domains outside the target volume, e.g. in the sea area.

4.3.2 Mineral resources

The ore potential in the coastal area in northern Uppland is correlated to the rock types and their characteristics. An assessment of the ore potential came to the conclusion that there is no potential for metallic and industrial mineral deposits within the candidate area at Forsmark. A potential for iron oxide mineralisation was recognised in an area south-west of the candidate area, predominantly in the felsic to metavolcanic rock, but the mineral deposits are small and have been assessed to be of no current economic value /Lindroos et al. 2004/. Felsic to metavolcanic rock is also dominant in rock domain RFM021, located north and offshore of the candidate area (Figure 4-7). There is no documented iron mineralisation in data available from the islands, but since most of this rock domain is located beneath the Baltic Sea from where no mineralogical data exist, the potential for iron oxide mineralisation in rock domain RFM021 cannot be totally excluded.

Table 5-8. The content of N, Cl, Ni and Nb in the construction material for typical BWR and PWR fuel assemblies.

Element	Weight in 1 fuel assembly (kg)						
	BWR Svea 96 Optima 2				PWR Areva 17·17		
	Cladding	Other	Fuel channel	Total[1]	Cladding	Other	Total[1]
N	0.002	0.002	0.005	0.009	0.0055	0.0058	0.011
Cl		$6 \cdot 10^{-6}$	$8 \cdot 10^{-6}$	$1.4 \cdot 10^{-5}$	$3 \cdot 10^{-6}$	$1.4 \cdot 10^{-5}$	$1.7 \cdot 10^{-5}$
Ni	0.02	1.1	0.86	1.99	0.27	2.19	2.46
Nb		0.0082	$8 \cdot 10^{-4}$	0.0091	1.08	0.09	1.17

1) Total sometimes appears to differ from the sum of the individual contributions due to rounding.

5.4 Initial state of the canister

5.4.1 Design premises relating to long-term safety

The process of defining the design premises for the canister is based on the overall strategy discussed in Section 5.1.1 and as described in Chapter 2 of the **Canister production report**. In the following the main design premises on the canister, as defined in the Design premises report /SKB 2009a/, are listed.

- "The canister shall withstand an isostatic load of 45 MPa, being the sum of maximum swelling pressure and maximum groundwater pressure.
- The copper corrosion barrier should remain intact after a 5 cm shear movement at a velocity of 1 m/s for buffer material properties of a 2,050 kg/m³ Ca-bentonite[10], for all locations and angles of the shearing fracture in the deposition hole, and for temperatures down to 0°C. The insert should maintain its pressure-bearing properties to isostatic loads.
- A nominal copper thickness of 5 cm, also considering the welds.
- The spent fuel properties and geometrical arrangement in the canister should further be such that criticality is avoided if water should enter a canister."

The design premise for the canister to withstand isostatic load also encompasses asymmetric loads due to uneven swelling of the bentonite. Temporary asymmetric loads could occur due to uneven saturation of the buffer or due to irregularities in the deposition hole. Irregularities in the deposition hole may also result in permanent asymmetric loads.

There are also some more indirect requirements on material composition and structure, and on the environment in the sealed canister. These are summarised as follows.

- "Gamma radiation causes hardness and brittleness in cast iron. Copper content in cast iron < 0.05%.
- Creep ductility: Grain size < 800 μm, Phosphorus content in copper: 30–100 ppm, Sulphur content in copper < 12 ppm.
- Brittleness of copper: Hydrogen content < 0.6 ppm.
- In addition: oxygen content of some tens of ppm can be allowed in the copper. However the material used for trial production has had a requirement < 5 ppm and before a change can be made further testing is needed.
- The quantity of nitric acid that can be formed in the insert shall be limited by replacing the atmosphere in the insert by > 90% argon. The permissible water quantity in the insert is set to 600 g."

There are also design premises on the canister from the spent fuel, which is a further specification of the requirement to prevent criticality:

- The material composition of the nodular cast iron shall be: Fe > 90%, C < 4.5% and Si < 6%.

The production and operation gives the following design premises for the copper canister:

- To allow ultrasonic testing the average grain size shall be less than 360 μm.

[10] It should be noted that the design premise concerns a Ca-bentonite since it is pessimistically assumed that the reference bentonite material will be transformed to the stiffer Ca-bentonite before the shearing event.

hole, neglecting the effects of incomplete homogenization. Analyses, presented in the **Buffer production report**, are made to show how to fulfil the design premise on buffer density.

The installed buffer density will depend on the density and dimensions of the installed blocks and pellets, i.e. the installed buffer mass, and the volume of the deposition hole and canister. The impact of the variations of volume of the canister and dimensions of the blocks on the installed buffer density can be neglected. The important parameters are the density of the blocks and pellets and the volume of the deposition hole. Over a random cross section of the deposition hole the installed density will vary due to:

- Variations of the diameter of the deposition hole.
- The placement of the buffer blocks with respect to the centre line of the deposition hole.
- The occurrence of spalling.

The impact on the variation in deposition hole diameter on the installed and corresponding saturated density can be determined assuming that the canister and ring shaped blocks are placed centred in each cross section. This will be the case if the centre point of each cross section is coincident with a vertical line, i.e. the drilling is straight.

Based on the distribution in block densities presented in Table 5-12, the variation in saturated density can be calculated for allowed increases in width of the pellet filled gap, or deposition hole radius, from the nominal. Results from such calculations are presented in Table 5-15. For a straight deposition hole with nominal diameter, the increase in width of the pellet filled gap corresponds to the maximum allowed depth of spalling. The number of deposition holes where this depth of spalling may occur as assessed when developing the current repository design /SKB 2009b/ (see also Figure 5-5) is also accounted for in Table 5-15. If the diameter deviates from the nominal the allowed depth of spalling is altered accordingly. If the deposition hole is not straight the allowed spalling decreases accordingly.

It is thus concluded that the methods for producing the buffer will yield densities at initial state that i) fulfil the specification of the reference design and ii) lead to densities after saturation that conform to the design premise on saturated density. Also, based on the results presented in Table 5-13, the densities after saturation without spalling are, with 99.9% confidence, expected to lie in the interval 2,000–2,020 kg/m^3 for sections around the canister and in the interval 2,025–2,045 kg/m^3 for sections above and below the canister. The former interval, which is narrower than that of the design premise, is of particular importance for the assessment of shear loads on the canister where a lower density yields lower shear loads on the canister. It is thus concluded that an upper limit on buffer density of 2,020 kg/m^3 for sections around the canister can be used in assessments of shear loads on the canister.

Installed geometry

The impact of the variation in canister placement and canister diameter on the buffer thickness can be neglected. The actual deposition hole diameter will deviate from the nominal. As described in the production section, analysis of measurements of diameters from the Prototype Repository shows that the standard deviation is 2.025 mm. The 99.9% confidence interval of the deposition hole diameter is 1. 743 < ø < 1.757 m. Assuming that the canister is placed in the centre of the deposition hole and there is no spalling results in a 99.9% confidence interval for the buffer thickness of 34.7 < buffer thickness < 35.3 cm.

Table 5-15. Results of calculations for of the saturated buffer density at the canister sections for allowed increases in width of the pellet filled gap from the nominal.

Allowed increase in width of pellet filled gap (m)	Number of deposition holes out of 6,000 with corresponding depth of spalling	99.9% confidence interval for the buffer density at saturation (kg/m^3)	(kg/m^3)
0.050	150	1,933	1,948
0.040	200	1,946	1,961
0.030	400	1,959	1,974
0.020	600	1,972	1,988
0.010	950	1,986	2,003

Modelling activity in AMF	Included processes, as indexed in process tables in Section 7.4	Code	Section(s) where modelling is reported	Note	Modelling report Reference	Modelling report In AMF
Solubilities	F14	"Simple functions"			**Radionuclide transport report**	TR-10-50
Radionuclide transport, near-field	F17, Bu25, BfT21 (The above three include, as sub-processes, F1, F12, F13, F14, Bu11, Bu12, BfT9, BfT10 and BfT11)	COMP23	Chapter 13		**Radionuclide transport report**	TR-10-50
Radionuclide transport, far-field	Ge24, consisting of sub-processes Ge11, Ge12, Ge13 and F1	FARF31 MARFA	Chapter 13		**Radionuclide transport report**	TR-10-50
Biosphere landscape model	Biosphere processes	Ecolego, MIKE_SHE, Pandora, ERICA	13.2		Avila et al. 2010	TR-10-06

Table 7-8. Links between process tables, AMF, Figure 7-4 and reporting in in this main report. Permafrost and glacial periods. The modelling activities in the left column correspond to yellow objects in Figure 7-4.

Modelling activity in AMF	Included processes, as indexed in process tables in Section 7.4	Code	Section(s) where modelling is reported	Note	Modelling report	
					Reference	In AMF
Permafrost modelling	F1, F2, Ge1	Numerical permafrost model	10.4.1, 10.4.3		In the **Climate report,** details in Hartikainen et al. 2010	In TR-10-49, details in TR-09-17
Ice sheet modelling	External processes, see SR-Site **Climate report**	UMISM	10.4.1		In the **Climate report**	In, TR-10-49, details in TR-09-19
GIA modelling; (Global Isostatic Adjustment)	External processes, see SR-Site **Climate report**	Numerical GIA model	10.4.1		In the **Climate report,** details in SKB 2006	In, TR-10-49, details in TR-06-23
FPI calculations; calculation of the occurrence of Full Perimeter Intersecting fractures in deposition tunnels (see Section 5.2.2)	Initial state issue	Matlab	10.4.5		Munier 2010	TR-10-21
Near-field stresses (geosphere)	Ge5	3DEC	10.4.4		Hökmark et al. 2010	TR-10-23
Reactivation	Ge6	3DEC	10.4.4		Hökmark et al. 2010	TR-10-23
Fracturing	Ge7	3DEC	10.4.4		Hökmark et al. 2010	TR-10-23
Groundwater composition over glacial cycle	Ge3, Ge11, Ge12, Ge21	PhreeqC	10.4.7		Salas et al. 2010	TR-10-58
Hydro, glacial domain	Ge3, Ge11	DarcyTools	10.4.6		Vidstrand et al. 2010 Selroos and Follin 2010	R-09-21 R-09-22
Hydro, ice location II	Ge3, Ge11	ConnectFlow	10.4.6		Joyce et al. 2010	R-09-20
Oxygen penetration during glacial period	Ge11, Ge15	PhreeqC, PHAST, analytical expressions	10.4.7		Sidborn et al. 2010	TR-10-57
Buffer and backfill freezing cases	Bu3, BfT2		10.4.8		Birgersson et al. 2010	TR-10-40
THC behaviour	Bu11, Bu12, Bu13, Bu14	PHAST	10.4.8		Sena et al. 2010	TR-10-59
Corrosion calculations (including buffer erosion calculations)	Bu18, C11	Analytical expressions (Excel)	10.4.9		SKB 2010d	TR-10-66
Solubilities	F14	“Simple functions”			**Radionuclide transport report**	TR-10-50
Radionuclide transport, near-field	F17, Bu25, BfT21 (The above three include, as sub-processes, F1, F12, F13, F14, Bu11, Bu12, BfT9, BfT10 and BfT11)	COMP23	Chapter 13		**Radionuclide transport report**	TR-10-50
Radionuclide transport, far-field	Ge24, consisting of sub-processes Ge11, Ge12, Ge13 and F1.	FARF31 MARFA	Chapter 13		**Radionuclide transport report**	TR-10-50
Biosphere landscape model	Biosphere processes	Ecolego, MIKE_SHE, Pandora, ERICA	13.2		Avila et al. 2010	TR-10-06

A criterion based on charge equivalents and not on separate concentrations for different ionic species has the advantage that the effect of ion exchange equilibrium is incorporated in a single criterion. Furthermore, modelling by /Neretnieks et al. 2009/ shows that during the transient of ion exchange, the concentration of Ca^{2+} in the seeping water drops at the bentonite-groundwater interface, whereas charge neutrality requires that the equivalent charge concentration remains constant.

Groundwaters of high ionic strengths would have a negative impact on the buffer and backfill properties, in particular on the backfill swelling pressure and hydraulic conductivity. In general, ionic strengths corresponding to NaCl concentrations of approximately 35 g/L (0.6 M NaCl) are an upper limit for maintaining backfill properties whereas the corresponding limit for the buffer is around 100 g/L (1.7 M NaCl). The limit of tolerable ionic strength is, however, highly dependent on the material properties of these components (see Section 5.5.3 and, for details, /Karnland et al. 2006/).

Colloid concentrations

The concentration of natural colloids should be low to avoid transport of radionuclides mediated by colloids. The stability of colloids is much decreased if the charge concentration of cations exceeds some millimol per litre. The condition discussed above for the stability of the buffer and backfill ($\Sigma q[M^{q+}]^{GW} > 4$ mM) is therefore also sufficient to keep the concentration of colloids suspended in groundwaters to a low level.

Concentrations of detrimental agents

Regarding canister corrosion, there should be low groundwater concentrations of other canister-corroding agents, in particular sulphide, HS^-. In addition, the groundwater should also have low concentrations of nutrients that may be used by sulphate reducing bacteria to produce sulphide. These are dissolved hydrogen, methane and organic carbon. For sulphide in the groundwater to pose a problem, earlier assessments demonstrated that, for an intact buffer, considerably higher concentrations than have ever been observed in Swedish groundwaters would be required. The quantitative extent of such corrosion also depends on the groundwater flow around the deposition hole and on the transport properties of fractures intersecting the hole.

Furthermore, low groundwater concentrations of agents detrimental to long-term stability of the buffer and backfill, in particular potassium and iron, are desirable, see the **Buffer, backfill and closure process report**, Section 3.5.10.

pH

Regarding pH, a criterion can be formulated from the point of view of buffer and backfill stability, see the **Buffer, backfill and closure process report**, Section 3.5.9:

$pH^{GW} < 11$

This is fulfilled for any natural groundwater in Sweden. However, construction and stray materials in the repository, in particular concrete, could contaminate the groundwater such that high pH values are reached.

Avoiding chloride assisted corrosion

A further requirement is that the combination of low pH values and high chloride concentrations should be avoided in order to exclude chloride assisted corrosion of the canister. In quantitative terms, the requirement is assigned the following criterion:

$pH^{GW} > 4$ and $[Cl^-]^{GW} < 2$ M

The basis for this criterion is documented in the **Fuel and canister process report**, Section 3.5.4.

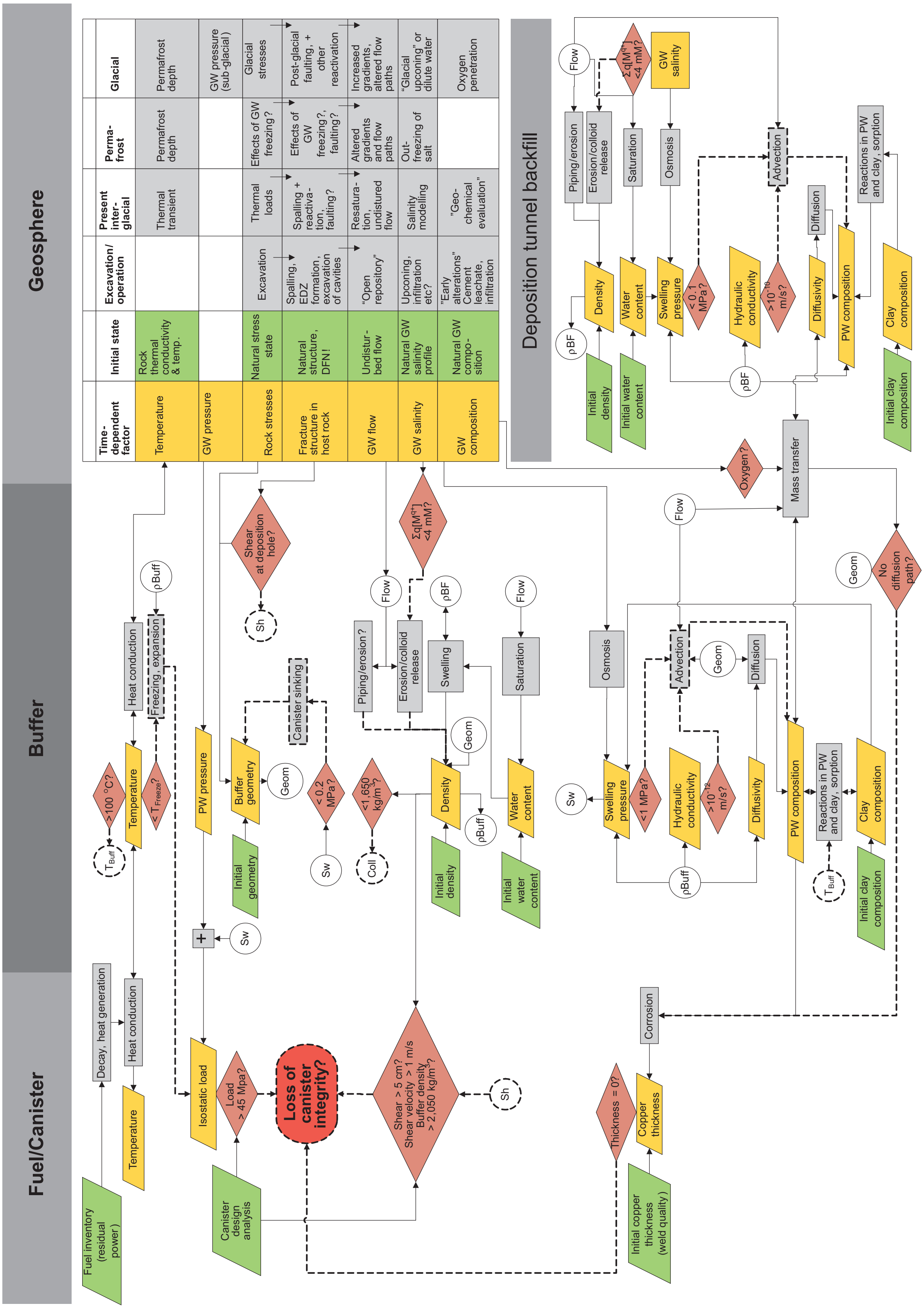


Figure 8-4. The SR-Site FEP chart, covering factors of relevance for containment. Colour coding: Initial state factors, Variables, Processes, Safety function indicators. Solid lines: Influences that always occur. Dashed lines: Influences if there is safety function indicator violation. Circles: Interrupted influence lines (to increase readability).