Guideline for reporting of OPERA contributions

OPERA-PU-NRG2122

Radioactive substances and ionizing radiation are used in medicine, industry, agriculture, research, education and electricity production. This generates radioactive waste. In the Netherlands, this waste is collected, treated and stored by COVRA (Centrale Organisatie Voor Radioactief Afval). After interim storage for a period of at least 100 years radioactive waste is intended for disposal. There is a worldwide scientific and technical consensus that geological disposal represents the safest long-term option for radioactive waste.

Geological disposal is emplacement of radioactive waste in deep underground formations. The goal of geological disposal is long-term isolation of radioactive waste from our living environment in order to avoid exposure of future generations to ionising radiation from the waste. OPERA (OnderzoeksProgramma Eindberging Radioactief Afval) is the Dutch research programme on geological disposal of radioactive waste.

Within OPERA, researchers of different organisations in different areas of expertise will cooperate on the initial, conditional Safety Cases for the host rocks Boom Clay and Zechstein rock salt. As the radioactive waste disposal process in the Netherlands is at an early, conceptual phase and the previous research programme has ended more than a decade ago, in OPERA a first preliminary or initial safety case will be developed to structure the research necessary for the eventual development of a repository in the Netherlands. The safety case is conditional since only the long-term safety of a generic repository will be assessed. The Dutch Ministry of Economic Affairs, Agriculture, finances OPERA and Innovation and the public limited liability company Electriciteits-Produktiemaatschappij Zuid-Nederland (EPZ) and coordinated by COVRA. Further details on OPERA and its outcomes can be accessed at www.covra.nl.

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Contents

Summary

The main objective of the OPERA research programme is to provide tools and data for the development of Safety Cases for national repository concepts for radioactive waste disposals in two host rocks present in the Netherlands, salt rock and Boom Clay.

A central aspect of the Safety Case is the execution of a safety assessment. Within the OPERA research programme, a generic safety assessment is being performed that evaluates all safety relevant aspects of the disposal concept (design of repository) and will assess the long-term safety of such a facility.

The execution of a safety assessment requires a sound and consistent methodology fit for purpose, a critical evaluation of assumptions used in the safety assessment calculations, the definition of evolution scenarios utilizing the identification and classification of relevant features, events, and processes (FEPs), a judgement of the impact of FEPs on safety functions, the evaluation of uncertainties, and the interpretation of the calculated results.

The development of models representing complex fundamental processes and the collection of data is performed within a variety of OPERA Tasks. Ultimately, the information generated in OPERA must be integrated into a balanced safety assessment model.

The main objective of the present report is to indicate the relation between the detailed technical and scientific work in OPERA and the safety assessment performed in WP7 of OPERA, and to provide guidelines for facilitating the exchange of information between the detailed technical-scientific works and the safety assessment.

Chapter 2 of this report summarizes the steps of the OPERA safety assessment methodology and additionally identifies which OPERA Tasks contribute to each step. Guidelines to streamline and focus the flow of information between the different OPERA Work Packages and Tasks are provided in Chapter 3.

Samenvatting

De belangrijkste doelstelling van het OPERA programma is het opzetten van methodes en gegevens voor de ontwikkeling van Safety Cases voor de Nederlandse eindbergingsconcepten voor radioactief afval in de gastgesteentes steenzout en Boomse Klei.

Een essentieel onderdeel van de Safety Case betreft de veiligheidsstudie die wordt verricht aan de hand van berekeningen, de zogenoemde “Safety Assessment”. Binnen het OPERA programma wordt een generieke veiligheidsstudie gedaan waarbinnen de veiligheids-relevante aspecten van het eindbergingsconcept worden geëvalueerd en de lange-termijn veiligheid wordt beoordeeld.

Het uitvoeren van een veiligheidsstudie behoeft een degelijke en consistente methodologie, een kritische evaluatie van de aannames voor de berekeningen, de definitie van mogelijke toekomstige scenario’s met behulp van de evaluatie van een lijst met verschijnselen, gebeurtenissen en processen, kortweg FEP’s (features, events and processes), een beoordeling van de invloed van FEP’s op veiligheidsfuncties van het systeem, een evaluatie van onzekerheden, en de interpretatie van de berekende resultaten.

De ontwikkeling van modellen die complexe fundamentele processen representeren en het bijeen brengen van gegevens wordt gedaan binnen diverse OPERA taken. Uiteindelijk wordt de informatie geïntegreerd in een rekenmodel voor de veiligheidsstudie.

Het primair doel van dit rapport is het aanduiden van de relatie tussen relatie tussen het gedetailleerde technisch-wetenschappelijk werk in OPERA en de geïntegreerde veiligheidsstudie die wordt uitgevoerd in OPERA's WP7, en het doen van aanbevelingen voor de uitwisseling van informatie die voor de veiligheidsstudie van belang is.

De opeenvolgende stappen van de OPERA veiligheidsstudie en de OPERA taken die hiertoe bijdragen zijn samengevat in Hoofdstuk 2. Aanbevelingen voor de uitwisseling van informatie die van belang is voor de OPERA veiligheidsstudie zijn benoemd in Hoofdstuk 3.

1. Introduction

1.1. Background

The main objective of the OPERA research programme is to provide tools and data for the development of Safety Cases for national repository concepts for radioactive waste disposals in two host rocks present in the Netherlands, salt rock and Boom Clay (Verhoef, 2011a; p.6). Within the OPERA context, the Safety Case has been explained as a collection of arguments in support of the long-term safety of the repository (Verhoef, 2011a; p.5). A safety case comprises the findings of a safety assessment and a statement of confidence in these findings.

A central aspect of the Safety Case is the execution of a safety assessment. Within the OPERA research programme, a generic safety assessment is being performed that evaluates all safety relevant aspects of the disposal concept (design of repository) and will assess the long-term safety of such a facility (Verhoef, 2011a; p.5).

The execution of a safety assessment requires a sound and consistent methodology fit for purpose, a critical evaluation of assumptions used in the safety assessment calculations, the definition of evolution scenarios utilizing the identification and classification of relevant features, events, and processes (FEPs), a judgement of the impact of FEPs on safety functions, the evaluation of uncertainties, and the interpretation of the calculated results. The methodology of the OPERA safety assessment has been explained in OPERA Deliverable OPERA-PU-NRG2121, "*Report on the safety assessment methodology*" (Grupa, 2014b).

OPERA Task 7.2.4: *Integrated modelling environment for safety assessment*, is responsible for integrating models of different processes and developing simple models that defensibly represent complex fundamental processes. The resulting model or set of models produces the safety assessment.

1.2. Objectives

The main objective of the present report is to indicate the relation between the detailed technical and scientific work in OPERA and the safety assessment performed in WP7 of OPERA, and to provide guidelines for facilitating the exchange of information between the detailed technical-scientific work and the safety assessment.

1.3. Realization

The partners NRG and EnviroLogic Inc. of the OPERA OSCAR consortium prepared this report.

1.4. Contents of this Report

Chapter 2 provides an overview of the relation between the detailed technical and scientific work in OPERA and the safety assessment performed in WP7 of OPERA, by summarizing the subsequent steps of the safety assessment as described in OPERA-PU-NRG2121 (Grupa, 2014b), and by indicating for each step the OPERA Tasks that contribute to that step of the safety assessment. Chapter 3 provides guidelines for efficiently exchanging information between the different OPERA Work Packages and Tasks. Concluding remarks are provided in Chapter 4.

2. Relation between OPERA tasks and safety assessment

In order to indicate the relation between the detailed technical-scientific OPERA research tasks and the safety assessment tasks, this chapter shortly describes each step of the OPERA safety assessment methodology (Grupa, 2014b) and points out what OPERA tasks contribute to that step.

2.1. *Expected results of the OPERA research*

The OPERA Safety Case is the basis by which the safety of long term disposal of radioactive waste in The Netherlands will be assessed (Verhoef, 2011b; p. 5). The OPERA Safety Case will consist of a set of reports with differing levels of system knowledge and process understanding (Grupa, 2014a; p.15). Approximately 40 OPERA R&D reports will form the knowledge base for radioactive waste disposal within the Dutch context. In addition, one or more OPERA synthesis reports will be compiled, as well as a summary report or brochure providing the high level, non-technical summary of the Safety Case.

The OPERA R&D reports are milestones in the OPERA Research Plan (Verhoef, 2011; Section II) and, as such, their general content and format are pre-defined. The level of detail found in these reports will be a function of the type and detail of the research defined by the OPERA Work Packages and Task Definitions. OPERA synthesis reports will balance the level of detail and, if they exist, identify any uncertainties. These uncertainties will be taken into account when the section "*Follow-up programmes and actions*" is prepared at synthesis level.

A substantial part of the information generated in OPERA will provide input to the post-closure safety assessment. The post-closure safety assessment is being developed in OPERA WP7 "*Scenario development and performance assessment*", and will be used to quantitatively assess the feasibility of geological disposal in the Netherlands.

The safety assessment translates the detailed system knowledge generated in OPERA Work Packages 1,3,4,5, and 6 into assumptions, parameters, and models used to calculate the long-term post-closure behavior of the disposal facility and assess potential impacts of simulated releases of radionuclides on mankind and the environment.

In the following sections each of steps of the Opera Safety Assessment Methodology is elucidated in more detail. In addition, an overview of the OPERA Research Tasks contributing to these steps is provided. A more detailed overview of each safety assessment step is provided in OPERA-PU-NRG2121 (Grupa, 2014b).

2.1. *OPERA safety assessment methodology - summary*

The figure below (slightly modified from Grupa, 2014b; p.18) shows the steps of the OPERA safety assessment methodology along with a general overview of the information needed to perform the safety assessment. From the representation of the safety assessment methodology shown in Figure 2-1 clearly a significant amount of information is needed to perform each step of the safety assessment. The following sections discuss in more detail the Tasks in OPERA that contribute to the each step of the safety assessment.

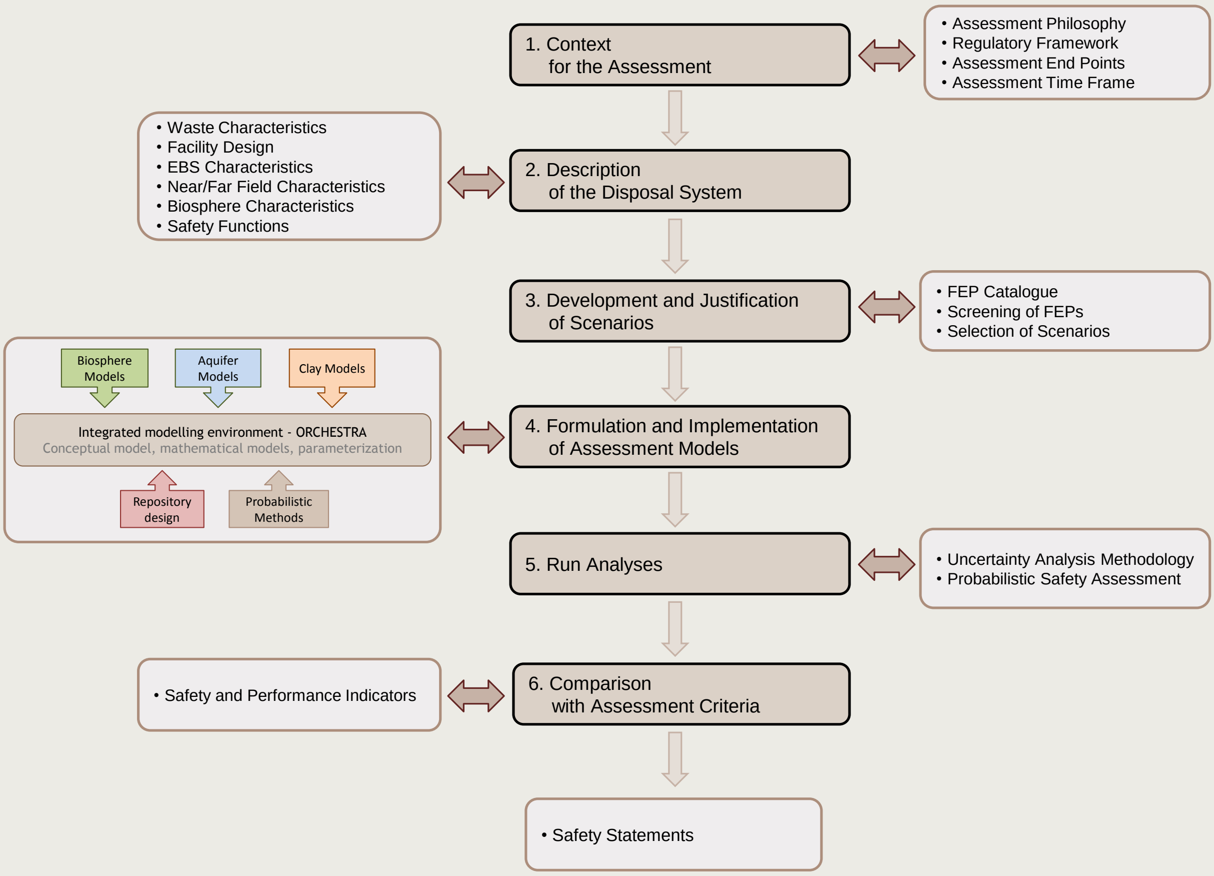

Figure 2-1 The recommended safety assessment methodology for the OPERA project

2.2. *Context for the Assessment*

This step in the safety assessment relates specifically to the quantitative assessment itself and supplements the more general presentation in the overall Safety Case Context. The main elements of the context of the OPERA Safety Case are provided by the OPERA Research Plan (Verhoef, 2011a) and COVRAs safety strategy document (Verhoef, 2014). In addition, the results of WP1.2 *Political requirement and societal expectations* and WP1.3 *Communicating the Safety Case* should help in formulating the context and expectations.

2.3. *Description of the Disposal System*

The description of the disposal system includes an overview of the identification and characterisation of the waste to be disposed of, the characterisation of the site, as well as the characterisation of the disposal concept, including the roles of the natural and engineered barriers and the safety functions that each is expected to provide in different time frames (Grupa, 2014b; Section 3.2).

The necessary information will primarily be acquired and substantiated in OPERA WP1 waste characteristics, WP3 Facility design, WP5.2 EBS characterisation, WP5.2 Near field characteristics, WP4 Far field characteristics (WP 5.2 and WP 4), and WP6 Biosphere characteristics. Together these data form the Knowledge Base of the safety assessment.

In order to ensure that safety assessment results are substantiated information sources, underlying assumptions and arguments will be documented in the OPERA research reports.

An overview of the OPERA Tasks contributing to building the knowledge base of the different entities of the disposal system is given in Table 2-1 and depicted in **Figure 2-2**.

Table 2-1 Overview of OPERA Tasks contributing to the "Description of the Disposal System"

OPERA Task	**Description**
	Waste Characteristics
Task 1.1.1	Definition of radionuclide inventory and matrix composition
Task 1.1.2	Alternative waste scenario's
	Facility Design
Task 3.1.1	Principal feasibility of reference design
Task 3.2.1	Design modifications
	EBS Characteristics
Task 5.1.1	HLW waste matrix corrosion processes
Task 5.1.2	LLW/ILW degradation processes and products
Task 5.1.3	Metal corrosion processes
Task 5.1.4	Cementitious material degradation
Task 5.1.5	Microbiological effects on the EBS and Boom Clay
Task 6.1.6	Gas migration in the EBS and in Boom Clay
	Near Field Characteristics
Task 4.2.1	Definition of boundary conditions for near-field model
Task 5.2.1	Geochemical properties and long-term evolution of Boom Clay
Task 5.2.2	Geochemical interactions in Boom Clay
Task 5.2.3	Geomechanical properties and thermo-hydromechanical evolution of Boom Clay
Task 6.1.1	Fundamental aspects of sorption processes
Task 6.1.2	Modelling of sorption processes
Task 6.1.3	Modelling of diffusion processes
Task 6.1.4	Mobility and presence of colloidal particles
Task 6.1.5	Non-diffusion related transport processes of solutes in Boom Clay
Task 6.1.6	Gas migration in the EBS and in Boom Clay
	Far Field Characteristics
Task 4.1.1	Description of the present geological and geohydrological properties of the geosphere
Task 4.1.2	Future evolution of the geological and geohydrological properties of the geosphere
Task 6.2.1	Modelling approach for hydraulic transport processes
Task 6.2.2	Modelling approach for radionuclide migration
	Far Field Characteristics
Task 6.3.1	Modelling approach for transport & uptake processes

A diagrammatic view of Table 2-1 is depicted in Figure 2-2.

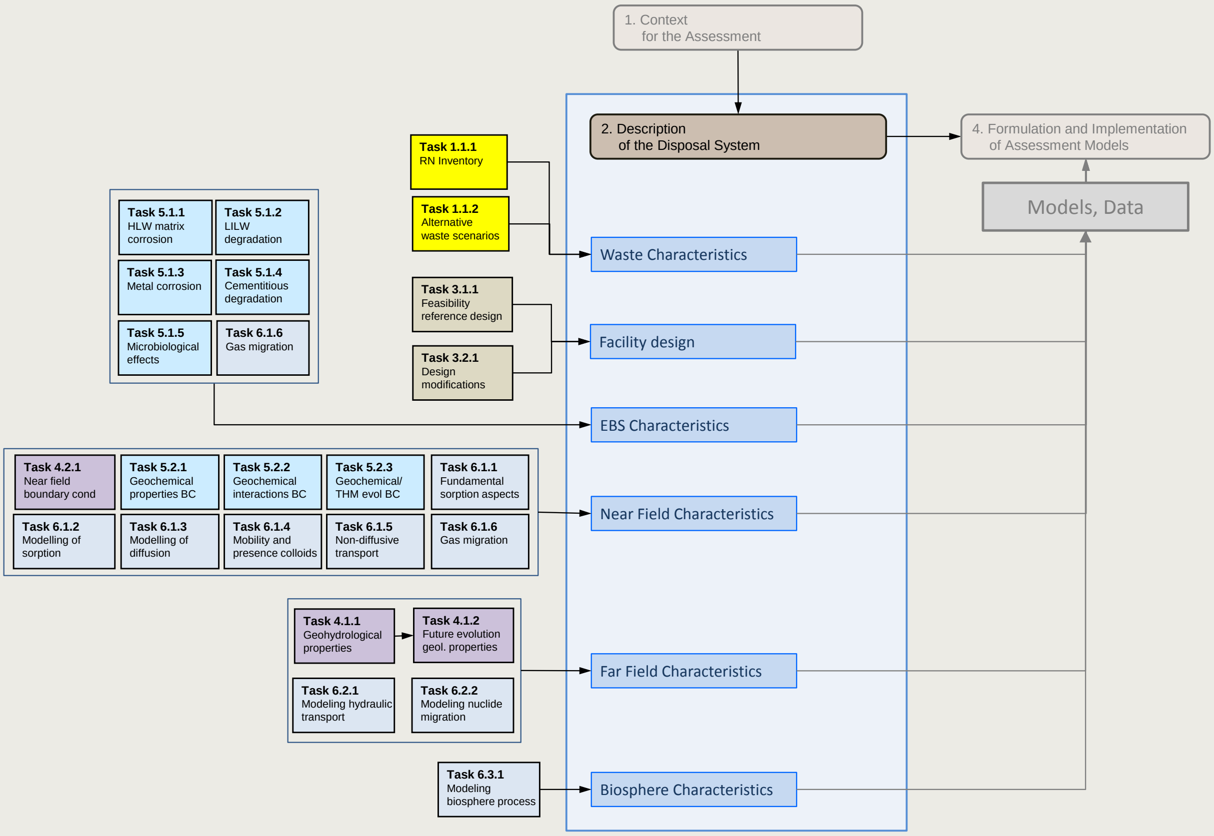

Figure 2-2 **Projection of OPERA Tasks on the safety assessment component "Description of the Disposal System"**

The "Description of the Disposal System" provides input to the "Formulation and implementation of assessment models" step in the Safety Assessment (Section 2.5).

2.4. Development and Justification of Scenarios

Scenarios are possible future states of the disposal system, and can be defined as combinations of features, events and processes (FEPs) that may affect the performance of the disposal system.

For OPERA a 'top-down' method for developing scenarios is used. This method is based on analyses of how the safety functions of the disposal system may be affected by possible features, events and processes, followed by auditing of the resulting scenarios against an appropriate list of FEPs. Included in the scenario definition are descriptions of radiological, thermal, hydraulic, mechanical, chemical and biological processes that may affect the disposal system (Grupa, 2014b; Section 3.3). Details of the scenario development process are given in the OPERA milestone document M7111 (Grupa, 2013). The list of FEPs has been substantiated in OPERA-PU-TNO2123A (Schelland, 2014).

Table 2-2 and Figure 2-3 provide an overview of the OPERA Tasks contributing to the "Development and Justification of Scenarios".

Table 2-2 Overview of OPERA Tasks contributing to the "Development and Justification of Scenarios"

OPERA Task	Description
Development and Justification of Scenarios	
Task 2.1.2C	FEPs, Features, Events, and Processes
Task 7.1.1	Scenario development

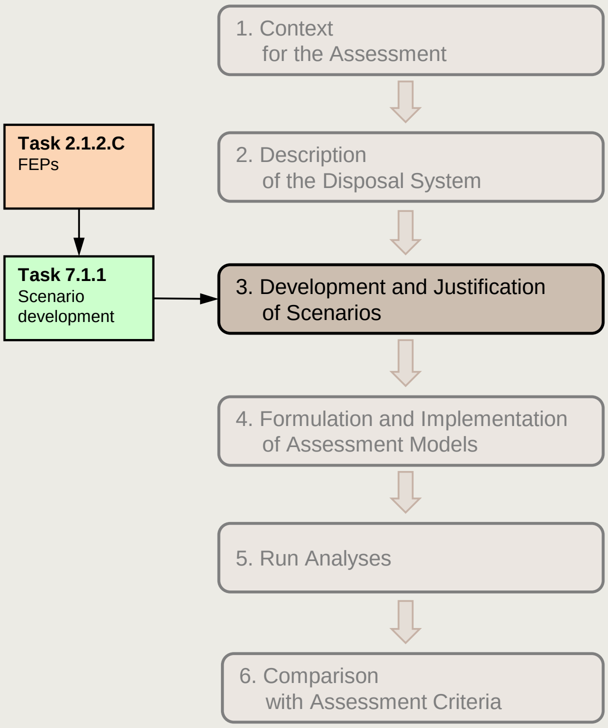

Figure 2-3 Projection of OPERA Tasks on the safety assessment component "Development and Justification of Scenarios"

2.5. Formulation and Implementation of Assessment Models

In OPERA an integrated assessment model will be developed and implemented in the safety assessment tool ORCHESTRA. This step of the safety assessment consists of the following components (Grupa, 2014b; Section 3.4):

- A conceptual model. The conceptual model provides a description of the components of the system and the interactions between these components.
- A mathematical model, which is a mathematical representation of the features and processes included in the conceptual model.
- A computer code, which is a software implementation of the mathematical model that facilitates performance of the assessment calculations.

Conceptual model

The basic premise of the OPERA safety assessment is that the radionuclides, upon their release from the waste packages, will be transported from the waste through several subsequent "compartments" of the disposal system and finally reach the receptors in the biosphere. The compartments distinguished in the OPERA conceptual model are the waste packages, the engineered barrier system, the repository, the geosphere (including the Boom Clay host rock) and the biosphere. The OPERA FEP database is in line with this structure (Schelland, 2014).

Mathematical model

The relevant features and processes of the disposal system will be translated into parameterized model representations of the *Clay*, *Aquifer*, and *Biosphere*, as well as into the integrated modelling environment. The integrated model will be developed in Task 7.2.4 *Integrated model for safety assessment*. Detailed models, resulting from specific research efforts, will be used to support parts of the integrated model. The logic is shown in the figure below, in which the horizontal arrows denote the input from the specific research.

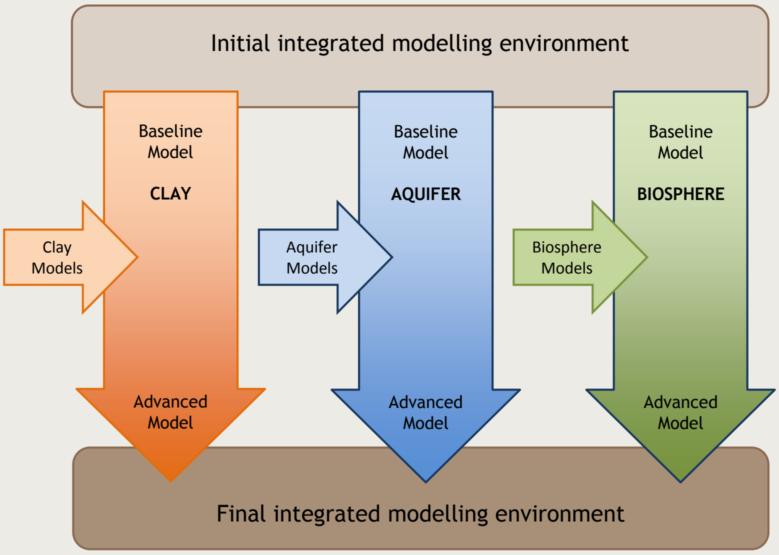

Figure 2-4 Procedure to refine the integrated safety assessment model environment

Initial investigations have already been performed in the previous Dutch programs. Though the Dutch disposal program is in an early development stage, the OPERA research program already contains various studies to refine the knowledge about the properties of the host rock and the representation of the aquifer system and biosphere.

The integrated model that will be used in OPERA is presently under development, and is referred to as the initial baseline model (Meeussen, 2014). Refinements to the models that emerge from the OPERA research tasks will be implemented in next iterations of the integrated tool.

Computer code

The integrated model will be implemented in the ORCHESTRA code, which couples the three PA compartment models, viz., the Clay, Aquifer, and Biosphere models. The coupling includes the data transfer from one compartment model to the next. This modelling environment enables the repeated calculations of the predefined scenarios needed for uncertainty analysis. The ORCHESTRA integrated modelling environment will allow the coupling of (simplified versions of) process models and the calculation of selected Safety and Performance Indicators.

An interfacing task in the safety assessment step *Formulation and Implementation of Models* is Task OPERA 7.1.2 *Scenario representation*, in which a strategy is being developed:

- to map how the various FEPs will be represented in the different compartments of the Performance Assessment model,
- to stylize the various distinguished scenarios,
- to record the decisions made in this mapping process, and
- to prepare for more detailed expert elicitation.

OPERA Task 7.1.2 is an important interface in transferring the relevant information developed in the detailed technical-scientific works in OPERA WP 3, 4, 5 and 6, and the actual safety assessment performed in WP7.

Table 2-3 and Figure 2-5 provide an overview of the OPERA Tasks contributing to the "Formulation and Implementation of Assessment Models", as will be performed in WP7.

The efforts will result in a description of the conceptual PA-model which is supported by the expertise developed in the detailed technical-scientific works in OPERA WP 3, 4, 5 and 6.

Table 2-3 Overview of OPERA Tasks contributing to the "Formulation and Implementation of Assessment Models"

OPERA Task	Description`
	Formulation and Implementation of Assessment Models
Task 7.1.2	Scenario representation
Task 7.2.1	PA model for radionuclide migration in Boom Clay
Task 7.2.2	PA model for radionuclide migration in an aquifer
Task 7.2.3	PA model for radionuclide migration and uptake in the biosphere
Task 7.2.4	Integrated modelling environment for safety assessment
Task 7.2.5	Parameterization of PA models

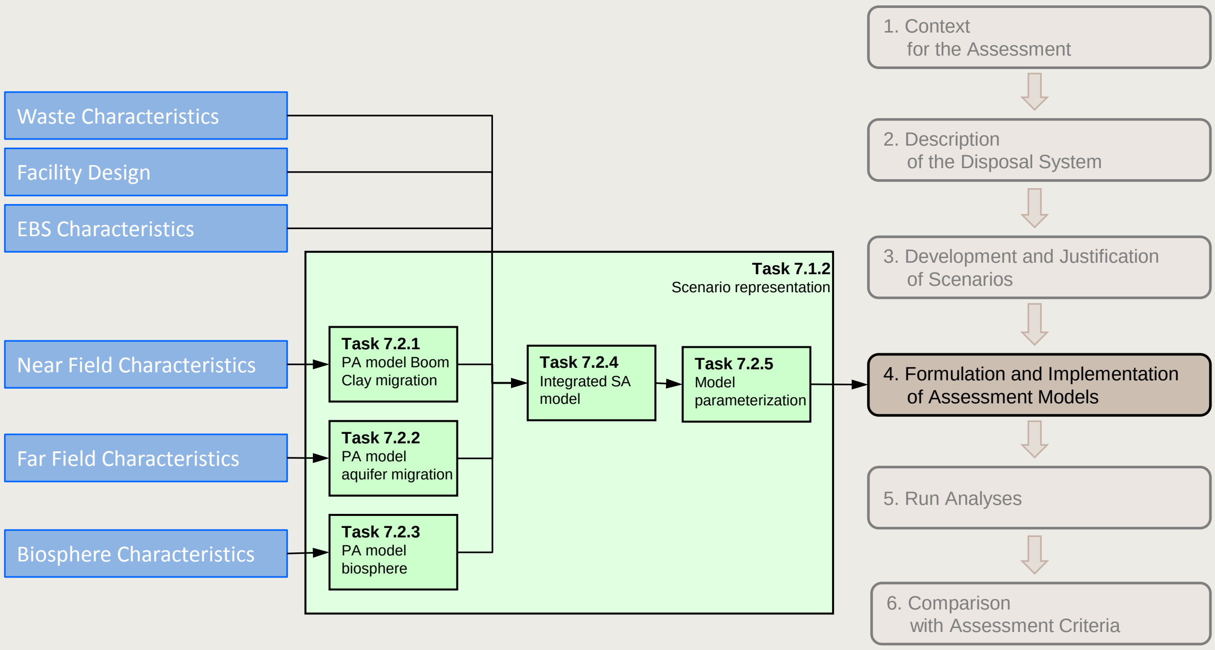

Figure 2-5 Projection of OPERA Tasks on the safety assessment component "Formulation and Implementation of Assessment Models"

2.6. Run analyses

The following calculational efforts are foreseen in OPERA WP7, more specifically in Task 7.3.3 (Grupa, 2012; p.17; Grupa, 2014b; Section 3.4):

- Each scenario defined by Task 7.1.1 and parameterized in Tasks 7.1.2 and 7.2.5 will be calculated, using the OPERA integrated model environment and the subsequent submodels built in WP7.2 (Grupa, 2013). Besides, preliminary calculations will be performed to test the (physical and chemical) consistency of the proposed uncertainty ranges and to identify possible numerical pitfalls or instabilities.
- Some sensitivity analyses are foreseen as preparation to the uncertainty analyses in OPERA WP 7.3. These analyses will be used in combination with expert judgment to identify the key uncertainties affecting the performance of the disposal system.

In OPERA WP 7.3 a strategy and the methods has been described for the handling of uncertainties (Becker, 2013).

Table 2-4 and Figure 2-6 provide an overview of the OPERA Tasks contributing to the "Run Analyses".

Table 2-4 Overview of OPERA Tasks contributing to the "Run Analyses"

OPERA Task	Description
	Run Analyses
Task 7.3.2	Definition of methods for the uncertainty analysis
Task 7.3.3	Safety assessment calculations

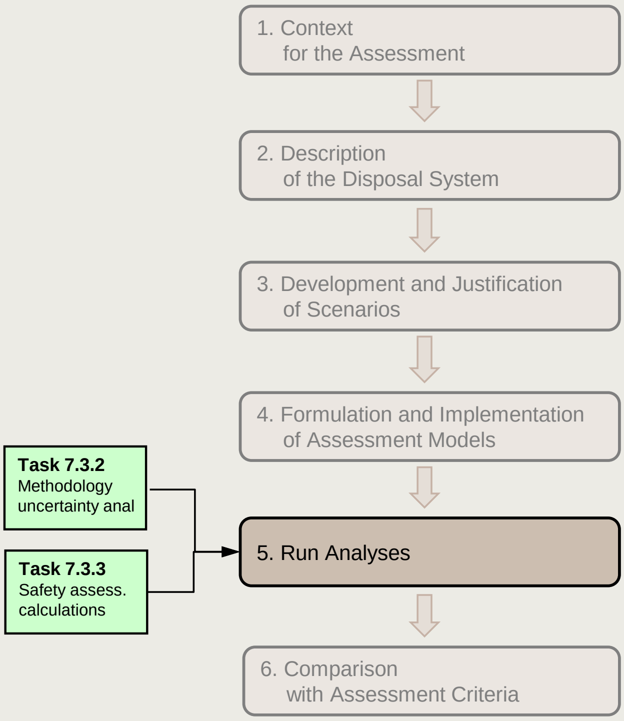

Figure 2-6 Projection of OPERA Tasks on the safety assessment component "Run Analyses"

2.7. Comparison With Assessment Criteria

The results of the safety assessment have to be compared with "assessment criteria". Usually, doses and risks are estimated for very long time periods and compared with appropriate criteria. In addition, NEA indicators (NEA, 2012) give a more elaborate approach to endpoints and comparison with assessment criteria. This is further developed in OPERA Task 7.3, where a list of safety and performance indicators will be established.

Table 2-5 and Figure 2-7 provide an overview of the OPERA Task contributing to the “Comparison With Assessment Criteria”.

Table 2-5 Overview of OPERA Tasks contributing to the “Comparison With Assessment Criteria”

OPERA Task	Description
	Comparison with Assessment Criteria
Task 7.3.1	Safety and Performance Indicators calculation methodology

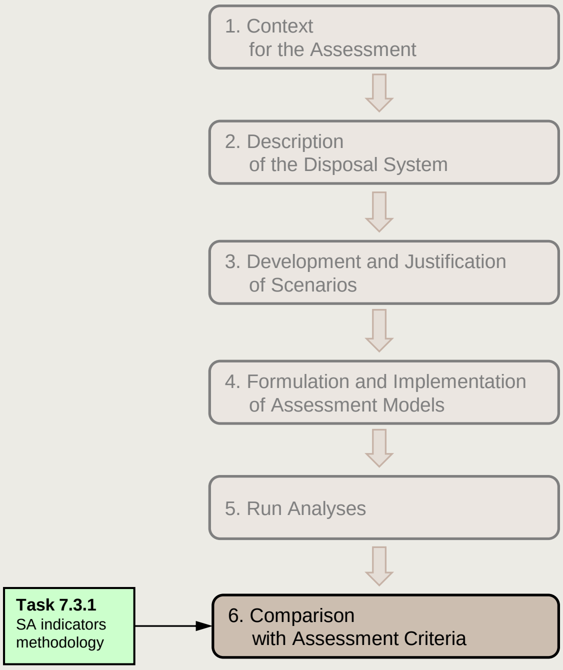

Figure 2-7 Projection of OPERA Tasks on the safety assessment component “Comparison With Assessment Criteria”

2.8. OPERA safety assessment - overview

As stated in the previous sections the actual safety assessment comprises a number of steps that together form the long-term safety assessment of the OPERA disposal system. An overview of all the OPERA Tasks contributing to the different steps of the OPERA safety assessment is given in Table 2-6.

Table 2-6 Overview of OPERA Tasks contributing to the safety assessment

OPERA Task	Description
	2. Description of the Disposal System
Waste Characteristics	
Task 1.1.1	Definition of radionuclide inventory and matrix composition
Task 1.1.2	Alternative waste scenario’s
Facility Design	
Task 3.1.1	Principal feasibility of reference design
Task 3.2.1	Design modifications
EBS Characteristics	
Task 5.1.1	HLW waste matrix corrosion processes
Task 5.1.2	LLW/ILW degradation processes and products
Task 5.1.3	Metal corrosion processes
Task 5.1.4	Cementitious material degradation
Task 5.1.5	Microbiological effects on the EBS and Boom Clay
Task 6.1.6	Gas migration in the EBS and in Boom Clay
Near Field Characteristics	
Task 4.2.1	Definition of boundary conditions for near-field model
Task 5.2.1	Geochemical properties and long-term evolution of Boom Clay
Task 5.2.2	Geochemical interactions in Boom Clay
Task 5.2.3	Geomechanical properties and thermo-hydromechanical evolution of Boom Clay
Task 6.1.1	Fundamental aspects of sorption processes
Task 6.1.2	Modelling of sorption processes
Task 6.1.3	Modelling of diffusion processes
Task 6.1.4	Mobility and presence of colloidal particles
Task 6.1.5	Non-diffusion related transport processes of solutes in Boom Clay
Task 6.1.6	Gas migration in the EBS and in Boom Clay
Far Field Characteristics	
Task 4.1.1	Description of the present geological and geohydrological properties of the geosphere
Task 4.1.2	Future evolution of the geological and geohydrological properties of the geosphere
Task 6.2.1	Modelling approach for hydraulic transport processes
Task 6.2.2	Modelling approach for radionuclide migration
Far Field Characteristics	
Task 6.3.1	Modelling approach for transport & uptake processes
	3. Development and Justification of Scenarios
Task 2.1.2C	FEPs, Features, Events, and Processes
Task 7.1.1	Scenario development
	4. Formulation and Implementation of Assessment Models
Task 7.1.2	Scenario representation
Task 7.2.1	PA model for radionuclide migration in Boom Clay
Task 7.2.2	PA model for radionuclide migration in an aquifer
Task 7.2.3	PA model for radionuclide migration and uptake in the biosphere
Task 7.2.4	Integrated modelling environment for safety assessment
Task 7.2.5	Parameterization of PA models
	5. Run Analyses
Task 7.3.2	Definition of methods for the uncertainty analysis
Task 7.3.3	Safety assessment calculations
	6. Comparison with Assessment Criteria
Task 7.3.1	Safety and Performance Indicators calculation methodology

It is clear that the coordination of all research information with the needs of the Safety Assessment is crucial to a successful execution of the OPERA safety assessment.

Since the safety assessment is being executed within OPERA WP7, coordinating the information needs is also part of this WP. The next chapter provides general guidelines to the OPERA researchers to handle the stream of information that is being generated within the programme.

3. Guidelines for the transfer of information between Research and Safety Assessment

The present chapter describes guidelines for managing the flow of information between the OPERA Work Packages and Tasks developing detailed system knowledge (WPs 1,3,4,5,6), and OPERA WP7, in which the system knowledge will be “translated” into assumptions, parameters, and models used to calculate the long-term post-closure behavior of the disposal facility and assess potential impacts of simulated releases of radionuclides on mankind and the environment.

The following aspects of information transfer are treated subsequently:

- Restrictions and boundary conditions of OPERA and the safety assessment
- Nature of the information needed for the safety assessment
- Parties responsible for providing information packages
- The way information will be exchanged

3.1. Restrictions and Boundary Conditions

At present the radioactive waste disposal program in the Netherlands is at an early, conceptual phase. Taking this into account, and realizing that the previous research programme, CORA, ended more than a decade ago, OPERA aims to develop a preliminary or initial conditional Safety Case to structure the research necessary for the eventual development of a repository in the Netherlands. This Safety Case only addresses the long-term safety of a generic repository (Verhoef, 2011a; p.13).

The key component of the OPERA Safety Case is the safety assessment which assesses the safety of a potential, generic repository design in Boom Clay at a generic depth of 500 m, under the condition that siting is excluded (Verhoef, 2011a; Section 4.3.1). This implies that the research is not connected to a specific location/site in the Netherlands.

The nature of the OPERA Safety Case and the purpose of the safety assessment pose restrictions on the information being generated in the Research Work Packages (WP 1,3,4,5,6), which serves as input to the safety assessment. The OPERA researchers should be aware of these conditions and restrictions such as the following examples (this list is not exhaustive):

- For the characterization of the geology and geohydrological behavior of Boom Clay shallow layers (depth < 400 m) or clay of limited layer thickness (<< 100 m) should be excluded (Verhoef, 2011a; p.10).
- Site-specific data concerning e.g. aquifers or geological features should not be linked to a specific location in the Netherlands.
- Only radionuclides with half-lives longer than 10 years need be considered as a source term for the safety assessment because only the long-term safety of a generic repository will be assessed (Verhoef, 2011a; p.3). Short-term safety concerns, e.g. in relation to the operational phase of the repository, are not addressed in OPERA.
- Due to the long term surface storage period foreseen in the Netherlands the heat output from heat generating radioactive waste will have diminished considerably, resulting in only a mild temperature effect for hydraulic, mechanical and chemical processes in the engineered barriers and the surrounding host rock after disposal.

Taking into account such requisites the scope of the research efforts performed in the OPERA WPs should be restricted and unnecessary complicated issues should be avoided.

3.2. What information is needed

Data, Models, and Uncertainties

For the long-term safety assessment a conceptual integrated computer model of the repository, the Boom Clay host rock, the far field (overburden, geosphere), and the biosphere will be developed (see also Section 2.5). A majority of the data and building blocks of the integrated model will rely on information generated in the OPERA WPs 1,3,4,5, and 6. In accordance with the objectives of OPERA, the data and models should include the identification and, to the extent possible, an estimation of the uncertainties that are attached to them (Verhoef, 2011a; Section 5.2).

The data and models generated in the OPERA WPs 1,3,4,5, and 6 should serve the purpose of the safety assessment, and therefore take into account the relevant features, events and processes (FEPs) that potentially may affect the long term safety of the disposal system as described in the following section.

Features, Events, and Processes

An important requisite of the information provided by the OPERA WPs 1,3,4,5, and 6 is that the models and data should describe and/or take into account only the features, events, and processes (FEPs) of the disposal system that are relevant to the long-term safety of the OPERA reference design.

As part of OPERAs project OSCAR (WP2), approximately 360 FEPs have been identified and listed and their relevance for OPERA has been described in OPERA-PU-TNO2123A and OPERA-PU-TNO2123B of the OPERA project OSCAR (Schelland, 2014). The following five classes of FEPs can be distinguished:

- External Factors, e.g. geological and climatic events and processes, and future human actions (excavations, drilling, mining, …);
- Waste Package Factors, e.g. waste forms and properties, thermal and chemical processes occurring in the waste;
- Repository Factors, an inventory of radiological, chemical, hydraulic, thermal, and physical/mechanical processes relevant for the evolution of the engineered barriers of the facility;
- Geosphere Factors, e.g. geochemical evolution of the geosphere, thermal and hydraulic processes, transport of contaminants;
- Biosphere Factors, e.g. processes influencing the future radiological impact on humans and the environment

Many of the approximately 360 FEPs will be included to some extent in the OPERA integrated safety assessment model either in the form of models or as (sets of) parameters. This implies that for each of these FEPs models and or data should be acquired.

Future evolutions, Scenarios

The OPERA safety assessment will be executed taking into account several possible future evolutions of the disposal system:

- A so-called "normal evolution scenario" (NES) of the disposal system, assuming the most probable, expected long-term evolution of the disposal system and the boundary conditions after the emplacement of the radioactive waste;
- A set of "altered evolution scenarios" (AES), describing the long-term evolution of the disposal system taking into account major disturbances of the disposal system.

For the altered evolution scenarios FEPs may come into play that potentially affect the long-term behavior of the repository, or its safety functions. For example the FEP "Sea Level Change" is not taken into account in the NES, but it may induce the AES "Flooding of the Site". An overview of the scenarios presently considered in OPERA has been provided in OPERA-PU-NRG7111 (Grupa, 2013; Section 5).

The message to OPERA researchers is that:

- the OPERA safety assessment will be performed taking into account several scenarios, i.e. possible future evolutions of the disposal system;
- a system of features, events, and processes, FEPs, that potentially may influence the long-term evolution and safety of the repository has been established;
- the FEP database can aid in the identification of data and models needed for the OPERA safety assessment.

3.3. Who will provide what information

Broadly speaking the OPERA safety assessment consists of two major disciplines:

- The generation and delivery of knowledge/information in the form of models and/or data serving as input for the safety assessment. This information is generated and/or provided by researchers within OPERA WPs 1,3,4,5, and 6, hereafter denoted as "Experts".
- The execution of the safety assessment itself, which is done within WP7, hereafter denoted as "Safety Assessors". That part of the work may also include the "translation" of detailed models provided by WPs 1,3,4,5,6 into a form that can be included in the safety assessment tool: ORCHESTRA.

In order to mutually exchange the relevant pieces of information it is necessary:

- For the Safety Assessors to inform the Experts about the purpose and execution of the safety assessment, its boundary conditions and limitations, the required information (e.g. model descriptions of specified phenomena and/or processes, data), and the modeling environment, comprising the conceptual ORCHESTRA model of the disposal system, and the safety assessment tool ORCHESTRA.
- For the Experts to acknowledge the information provided by the Safety Assessors with respect to the purpose and restrictions of the safety assessment and to provide data and model descriptions of specified phenomena and/or processes requested by the Safety Assessors which are fit for purpose.

For the exchange of information the following steps are proposed:

- WP7 will inform the Experts about the purpose and execution of the safety assessment, and its boundary conditions and restrictions;
- WP7 will, on the basis of the OPERA FEP catalogue, identify the FEPs that are relevant for the safety assessment and communicate those FEPs to the relevant OPERA Tasks;
- WP7 will provide information to the Experts about ORCHESTRA and the status of the Integrated Model that is being developed for the safety assessment;
- The Experts (WPs 1,3,4,5,6) may comment on this information and will develop and provide information (detailed data, models, uncertainty estimates) on specified features, phenomena and/or processes relevant to the disposal system. The information should be in line with the information needed for WP7, i.e. the long-term safety assessment, and should take into account the restrictions and boundary conditions mentioned in Section 3.1;
- WP7 will integrate the detailed data and models either directly into ORCHESTRA or translate the information into a form that is manageable by ORCHESTRA to perform the safety assessment.

3.4. How will the exchange of information take place

For streamlining the flow of information between the Safety Assessors and the Experts, the following steps are proposed:

- The overall procedure for the exchange of information will be elucidated at the November 2014 Expert Meeting;
- In dedicated workshops and/or meetings the “Safety Assessors” from WP7 and the “Experts” from WPs 1,3,4,5,6 should interact to discuss what is needed for the WP7 safety assessment, and what can be delivered from WPs 1,3,4,5,6.
- The process is initiated and managed by WP7. This process includes the documentation of the exchange of information.

4. Concluding remarks

The main objective of the present report is to raise the OPERA researcher's awareness about the relation between their often-detailed technical and scientific work to the OPERA safety assessment, and to provide guidelines to facilitate the exchange of safety assessment information.

The methodology adopted for the OPERA safety assessment has been explained, and, in addition, OPERA Tasks contributing to each step of the safety assessment have been identified.

Given the restrictions and boundary conditions of OPERA and the safety assessment, an overview is provided of the nature of the information that is needed for the safety assessment.

Guidelines and recommendations are provided to streamline the flow of information between the different OPERA Work Packages and Tasks and to focus the contributions to the OPERA integrated safety assessment model.

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Appendix 1 Listing of OPERA Tasks

The following table and subsequent figure list the OPERA Tasks (Verhoef, 2011; Table 3).

Table 5-1 Overview of OPERA Tasks

OPERA Task	Description
WP1	Safety Case context
WP1.1	Waste characteristics
Task 1.1.1	Definition of radionuclide inventory and matrix composition
Task 1.1.2	Alternative waste scenario's
WP1.2	Political requirement and societal expectations
Task 1.2.1	Arena or stakeholder analysis
Task 1.2.2	Legal requirements
Task 1.2.3	Retrievability and staged closure
Task 1.2.4	Public & stakeholder involvement
WP1.3	Communicating the Safety Case
Task 1.3.1	Communicating Safety Case results
WP2	Safety Case
WP2.1	Definition of the Safety Case
Task 2.1.1	Structure of the Safety Case
Task 2.1.2	Safety assessment methodology
Task 2.1.3	Review of ongoing OPERA programme
WP2.2	Repository design in rock salt
Task 2.2.1	Evaluation of current knowledge for building the Safety Case
WP3	Repository Design
WP3.1	Feasibility studies
Task 3.1.1	Principal feasibility of reference design
WP3.2	Design modification
Task 3.2.1	Design modifications
WP4	Geology and Geohydrology
WP4.1	Geology and geohydrological behaviour of the geosphere
Task 4.1.1	Description of the present geological and geohydrological properties of the geosphere
Task 4.1.2	Future evolution of the geological and geohydrological properties of the geosphere
WP4.2	Geohydrological boundary conditions for the near-field
Task 4.2.1	Definition of boundary conditions for near-field model
Task 4.2.2	Favourable geohydrological settings
WP5	Geochemistry and geomechanics
WP5.1	Geochemical behaviour of EBS
Task 5.1.1	HLW waste matrix corrosion processes
Task 5.1.2	LLW/ILW degradation processes and products
Task 5.1.3	Metal corrosion processes
Task 5.1.4	Cementitious material degradation
Task 5.1.5	Microbiological effects on the EBS and Boom Clay
WP5.2	Properties, evolution and interactions of the Boom Clay
Task 5.2.1	Geochemical properties and long-term evolution of Boom Clay
Task 5.2.2	Geochemical interactions in Boom Clay
Task 5.2.3	Geomechanical properties and thermo-hydromechanical evolution of Boom Clay
WP6	Radionuclide migration
WP6.1	Radionuclide migration in Boom Clay

OPERA Task	Description
Task 6.1.1	Fundamental aspects of sorption processes
Task 6.1.2	Modelling of sorption processes
Task 6.1.3	Modelling of diffusion processes
Task 6.1.4	Mobility and presence of colloidal particles
Task 6.1.5	Non-diffusion related transport processes of solutes in Boom Clay
Task 6.1.6	Gas migration in the EBS and in Boom Clay
WP6.2	Radionuclide migration in an aquifer
Task 6.2.1	Modelling approach for hydraulic transport processes
Task 6.2.2	Modelling approach for radionuclide migration
WP6.3	Radionuclide migration and uptake in the biosphere
Task 6.3.1	Modelling approach for transport & uptake processes
WP7	Scenario development and performance assessment
WP7.1	Scenario
Task 7.1.1	Scenario development
Task 7.1.2	Scenario representation
WP7.2	PA model development and parameterization
Task 7.2.1	PA model for radionuclide migration in Boom Clay
Task 7.2.2	PA model for radionuclide migration in an aquifer
Task 7.2.3	PA model for radionuclide migration and uptake in the biosphere
Task 7.2.4	Integrated modelling environment for safety assessment
Task 7.2.5	Parameterization of PA models
WP7.3	Safety assessment
Task 7.3.1	Safety and Performance Indicators calculation methodology
Task 7.3.2	Definition of methods for the uncertainty analysis
Task 7.3.3	Safety assessment calculations

WP1

- **Task 1.1.1** RN Inventory
- **Task 1.1.2** Alternative waste scenarios
- **Task 1.2.1** Stakeholder Analysis
- **Task 1.2.2** Legal requirements
- **Task 1.2.3** Retrievability
- **Task 1.2.4** Stakeholder involvement
- **Task 1.3.1** Communicating SC results

WP2

- **Task 2.1.1.B** Safety Case structure
- **Task 2.1.1.C** Safety statements
- **Task 2.1.2.A** Safety assess. methodology
- **Task 2.1.2.B** Guideline OPERA report
- **Task 2.1.2.C** FEPs
- **Task 2.2.1** Repository design rock salt

WP3

- **Task 3.1.1** Feasibility reference design
- **Task 3.2.1** Design modifications

WP4

- **Task 4.1.1** Geohydrological properties
- **Task 4.1.2** Future evolution geol. properties
- **Task 4.2.1** Near field boundary cond

WP5

- **Task 5.1.1** HLW matrix corrosion
- **Task 5.1.2** LILW degradation
- **Task 5.1.3** Metal corrosion
- **Task 5.1.4** Cementitious degradation
- **Task 5.1.5** Microbiological effects
- **Task 5.2.1** Geochemical properties BC
- **Task 5.2.2** Geochemical interactions BC
- **Task 5.2.3** Geochemical/ THM evol BC

WP6

- **Task 6.1.1** Fundamental sorption aspects
- **Task 6.1.2** Modelling of sorption
- **Task 6.1.3** Modelling of diffusion
- **Task 6.1.4** Mobility and presence colloids
- **Task 6.1.5** Non-diffusive transport
- **Task 6.1.6** Gas migration
- **Task 6.2.1** Modeling hydraulic transport
- **Task 6.2.2** Modeling nuclide migration
- **Task 6.3.1** Modeling biosphere process

WP7

- **Task 7.1.1** Scenario development
- **Task 7.1.2** Scenario representation
- **Task 7.2.1** PA Boom Clay model
- **Task 7.2.1** PA model Boom Clay migration
- **Task 7.2.2** PA model aquifer migration
- **Task 7.2.3** PA model biosphere
- **Task 7.2.4** Integrated SA model
- **Task 7.2.5** Model parameterization
- **Task 7.3.1** SA indicators methodology
- **Task 7.3.2** Methodology uncertainty anal
- **Task 7.3.3** Safety assess. calculations

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