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Conceptual Model Development:

Approaches, Assumptions and Level of Detail

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Workshop on Performance Assessments of Near-Surface Disposal Facilities: FEPs Analysis, Scenario and Conceptual Model Development, and Code Selection

August 29 –30, 2012 , US NRC

Outline

- Part 1 - ISAM methodology
  - Definition of Conceptual Model
  - Role in a Safety Assessment
  - Approaches to development
  - Level of detail
- Part 2 - Experiences from application
  - Examples of conceptual models
  - From Conceptual Models to Mathematical Models
  - Analysis of conceptual uncertainties

CONCEPTUAL MODELS
ISAM METHODOLOGY

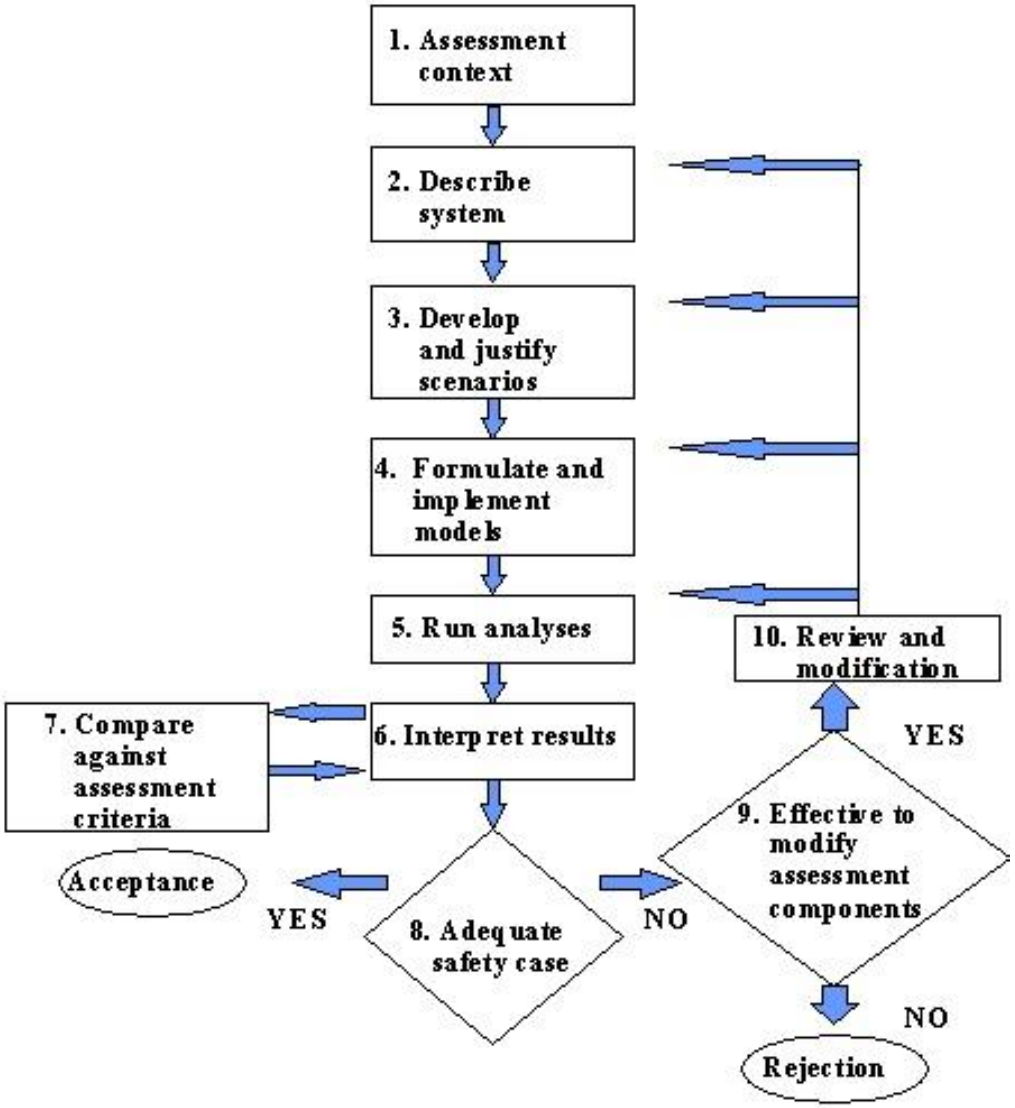
Conceptual Model Definition

The conceptual model is a set of model-level assumptions (about dimensionality, boundary conditions, FEPs, FEPs relationships, etc) defined for each scenario included in the Safety Assessment.

Components of a conceptual model

A conceptual model should comprise a description of:

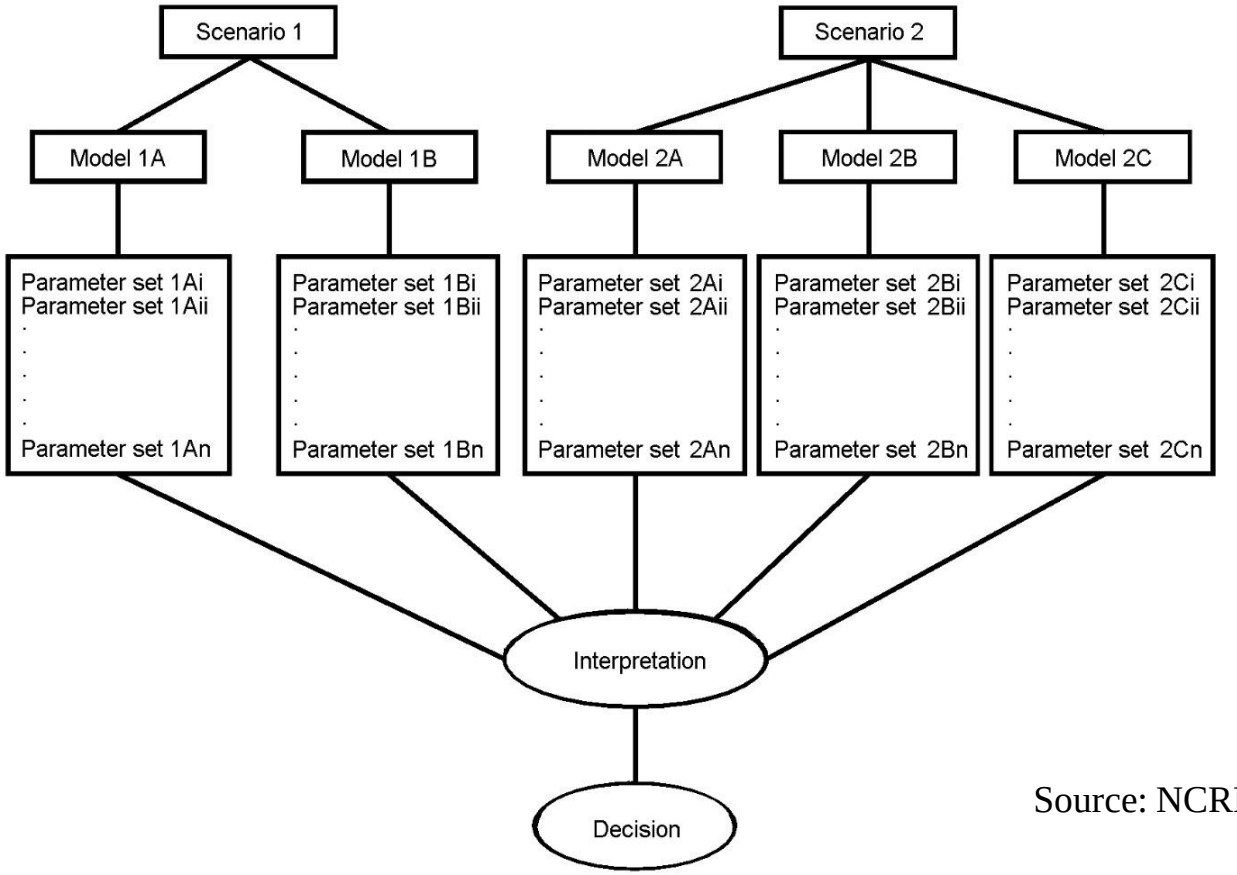
- The model FEPs
- The relationships between these FEPs
- The model´s scope of application in spatial and temporal terms (the model domain) – this includes the initial and boundary conditions



In the ISAM methodology the development of the Conceptual Models is an initial step of the formulation of mathematical models

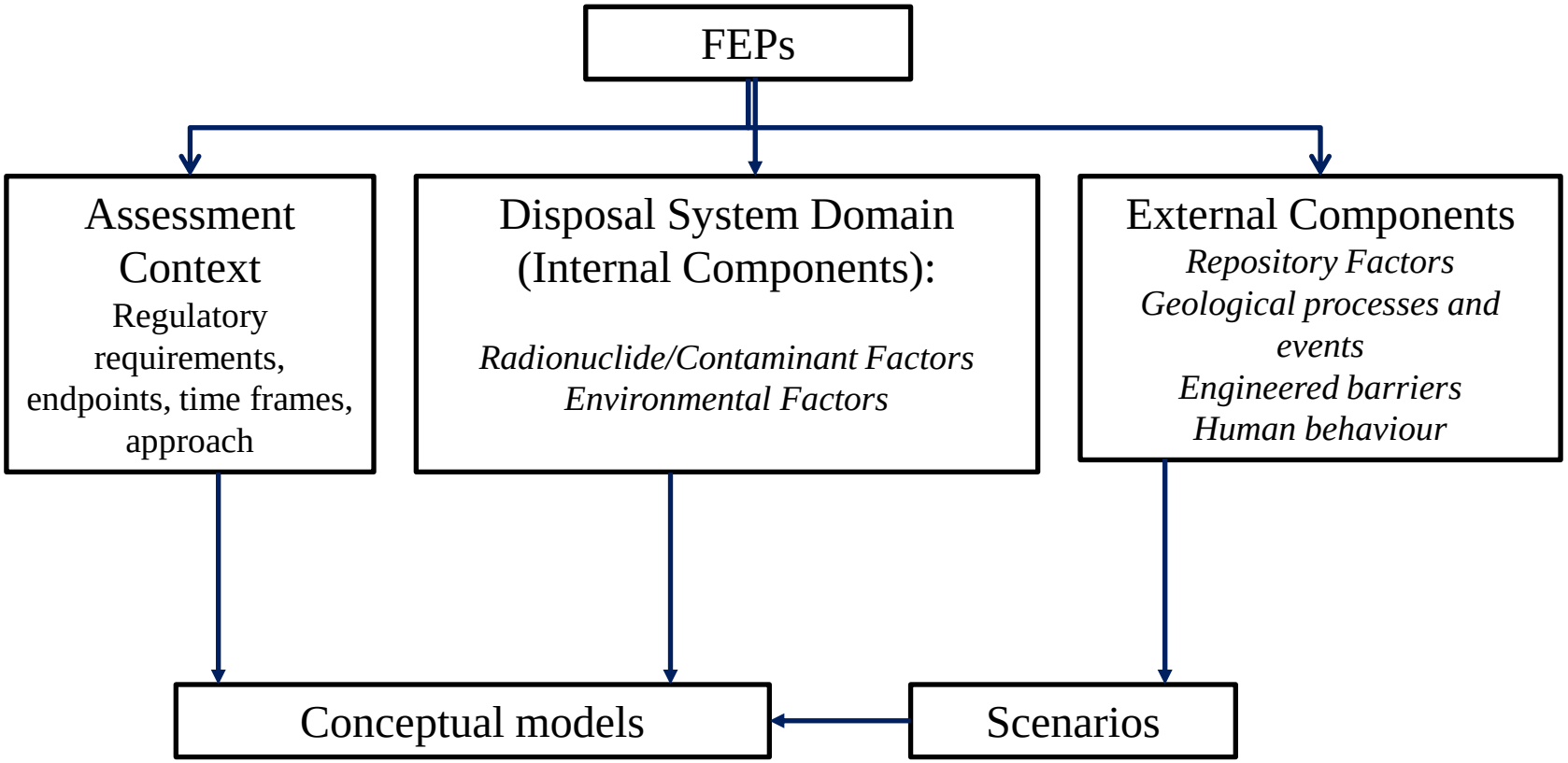
Source: IAEA, 2004

From scenarios to models



Source: NCRP Report 152

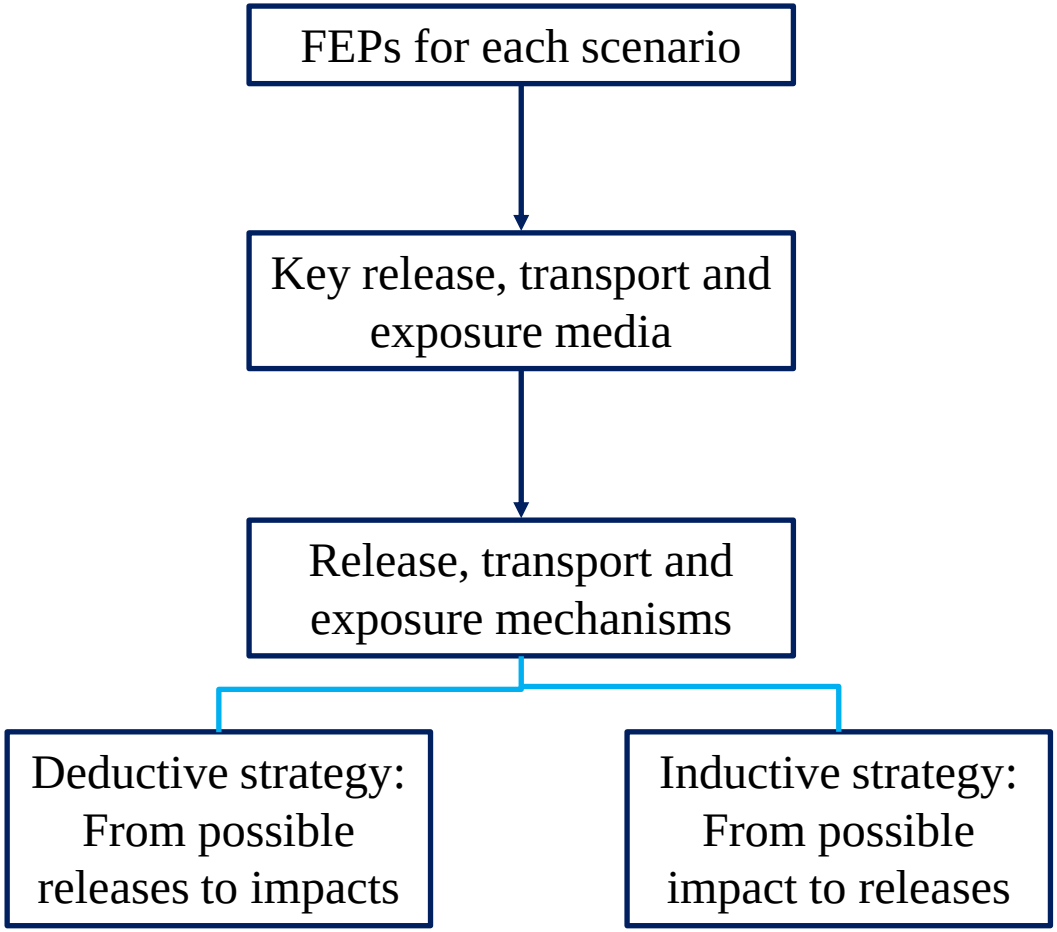
FEPs - Scenarios - Conceptual Models



Approaches to conceptual model development

- SACO approach
- Influence diagram approach
- Interaction matrix approach

The SACO approach



The interaction matrix approach

Component A 1,1	Influence of A on B 1,2
Influence of B on A 2,1	Component B 2,2

A connected chain of interactions through the matrix is called a PATHWAY

Ecolego Concept

- Tool for development and hierarchical visualization of conceptual models using interaction matrices
- Link to a FEP database
- Possibility for screening and ranking of FEPs by several criteria
- Recording of reviewers comments
- Version handling
- Automatic report generator.

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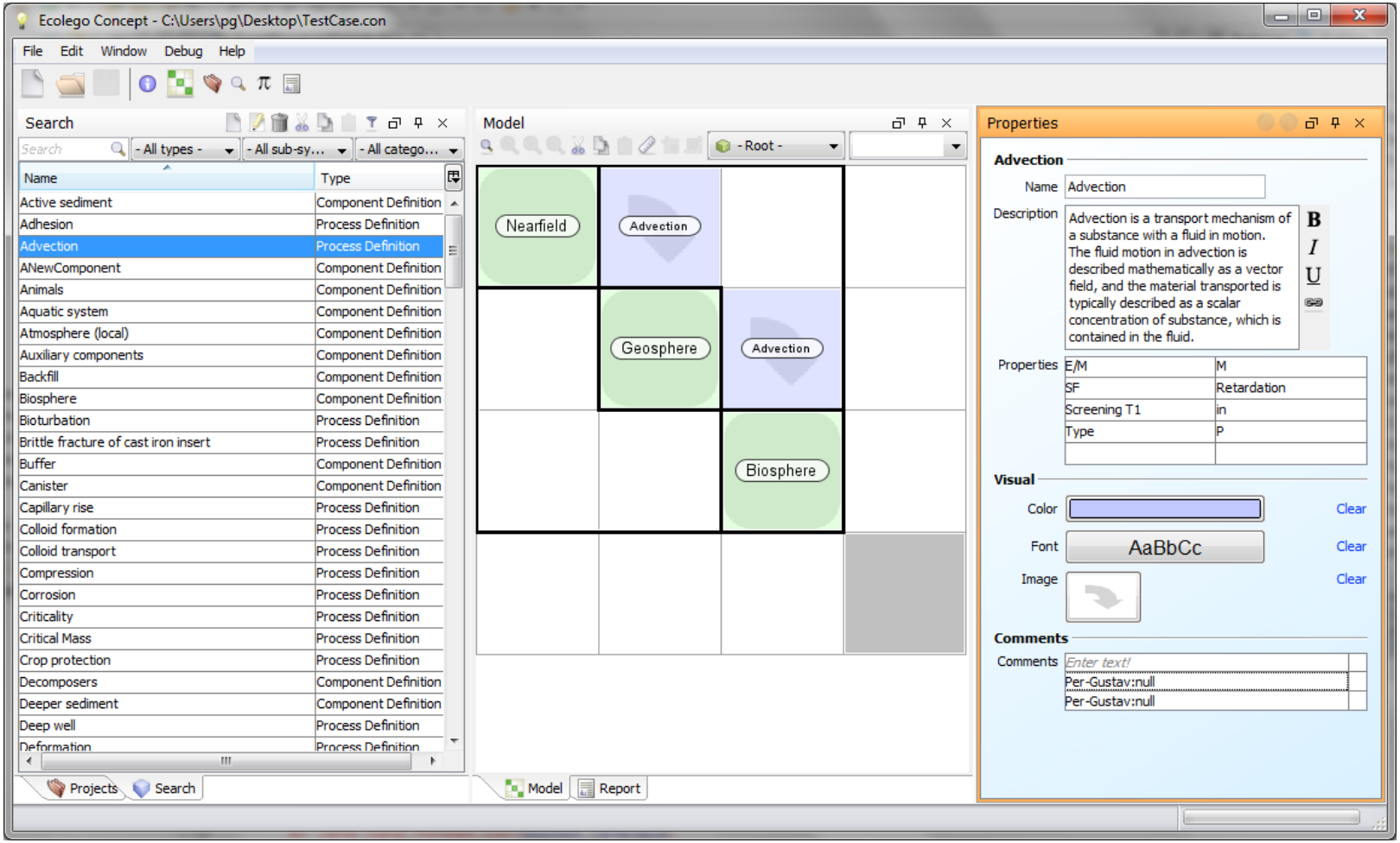
Graphical User Interface



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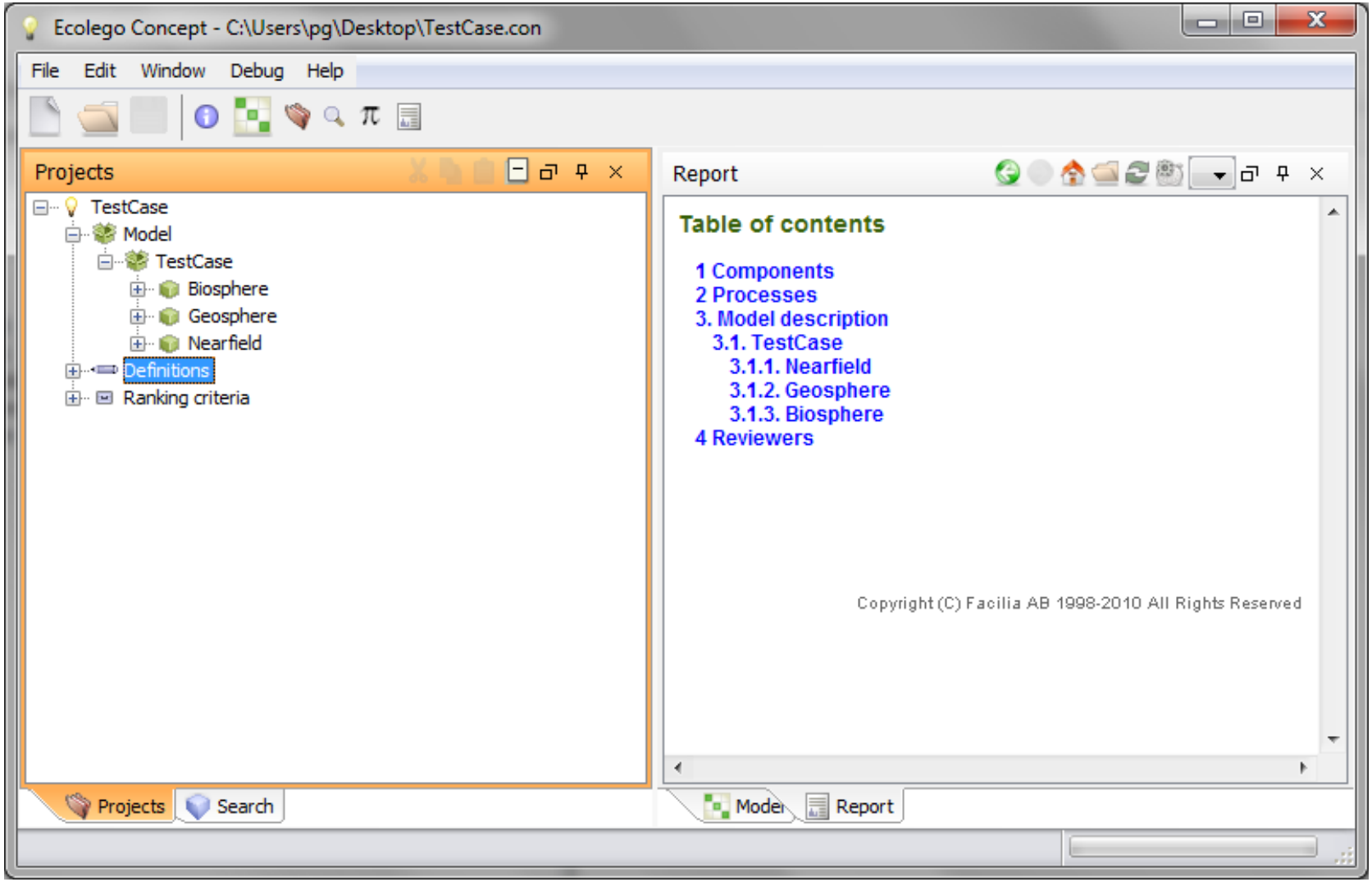
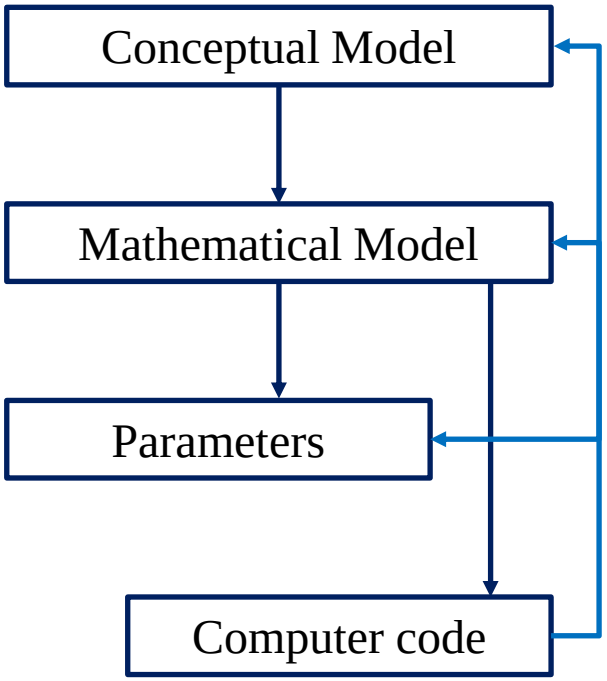
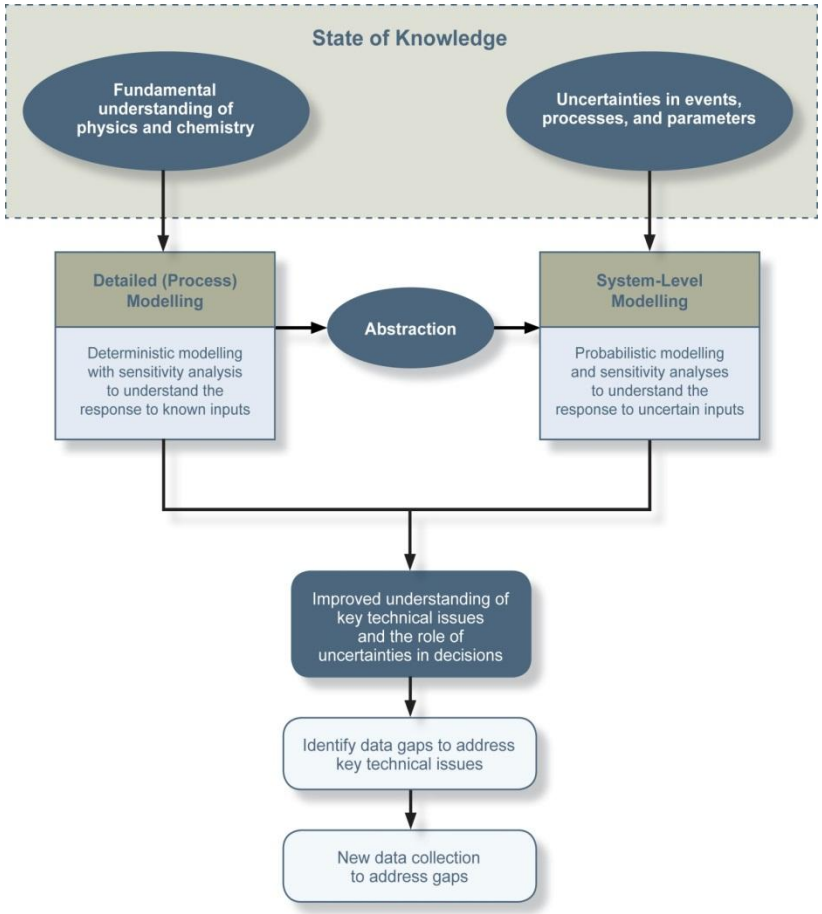
Report generator - html and PDF reports



Development of models for quantitative assessments



Types of models and level of detail



Structure of a safety assessment model showing the relationship between process and system-level modeling

Courtesy from Matt Kozak

EXAMPLES OF CONCEPTUAL MODELS

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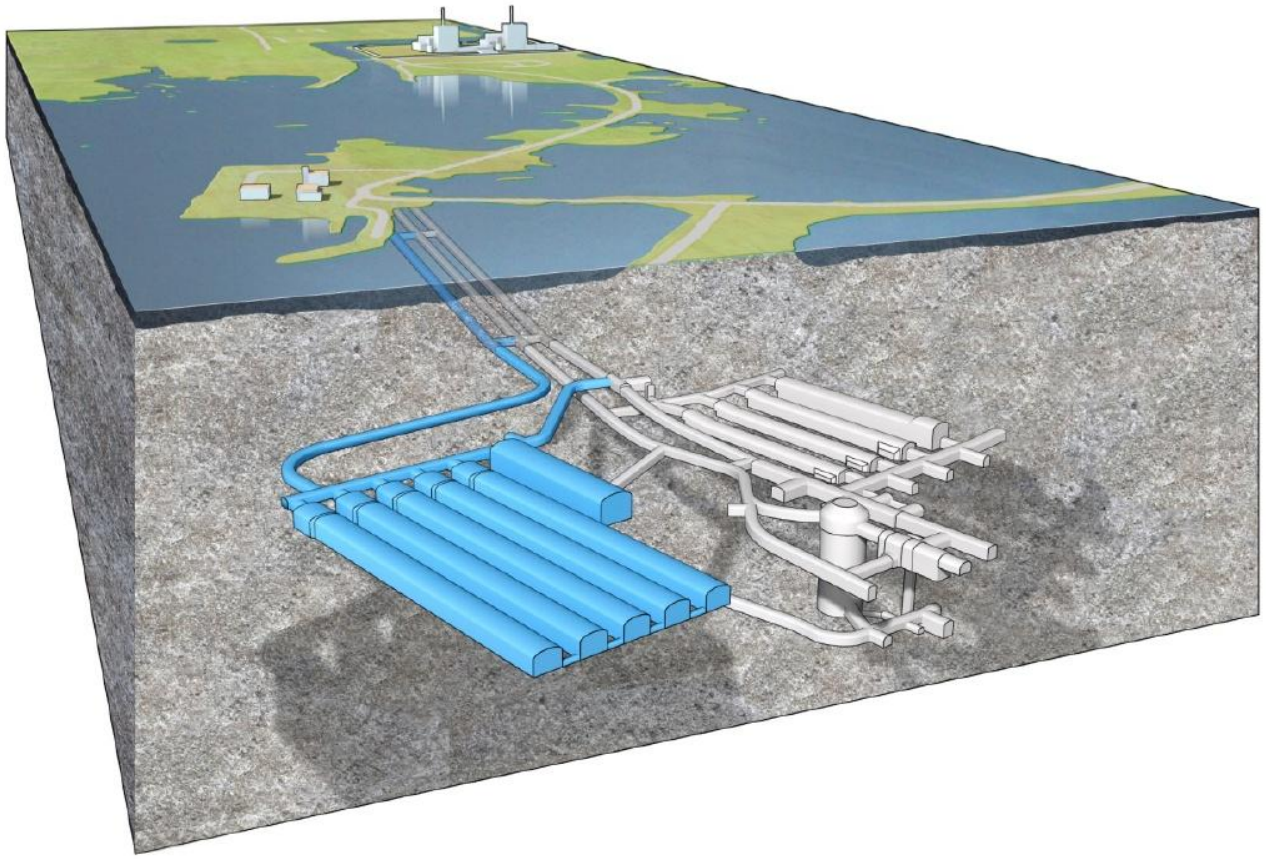
SFR-2020



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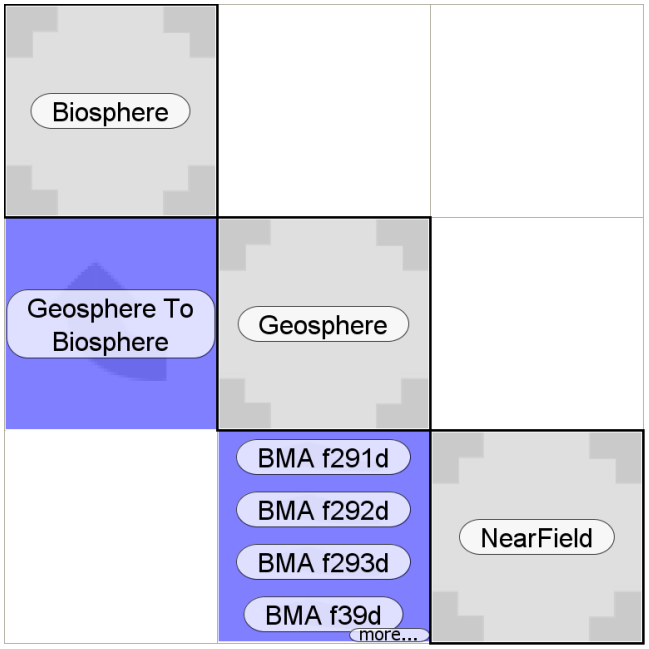
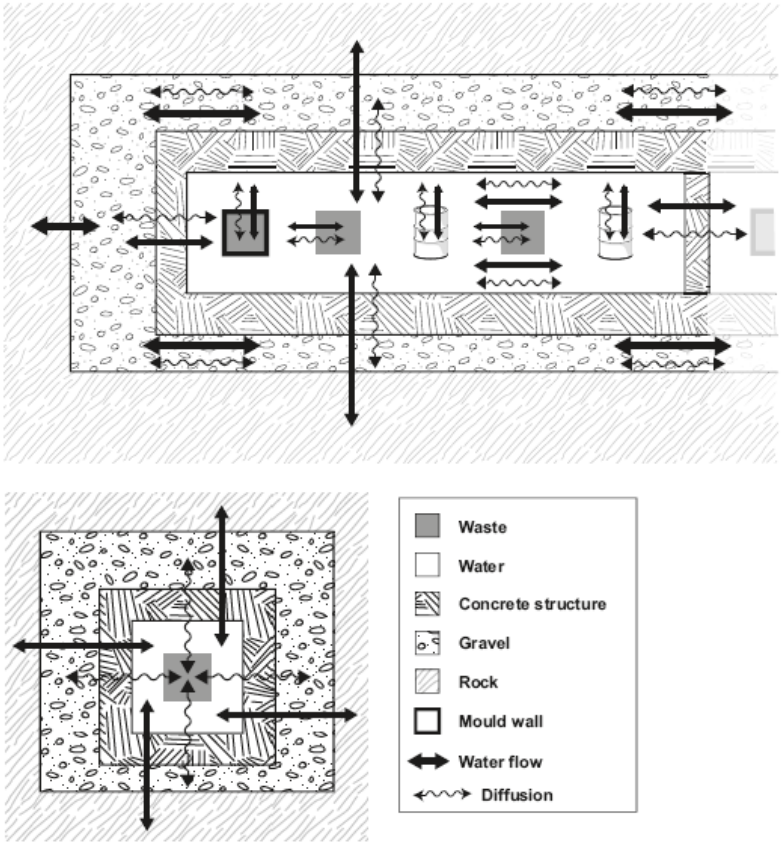
Model of the whole disposal system



Near field conceptual model (BMA)



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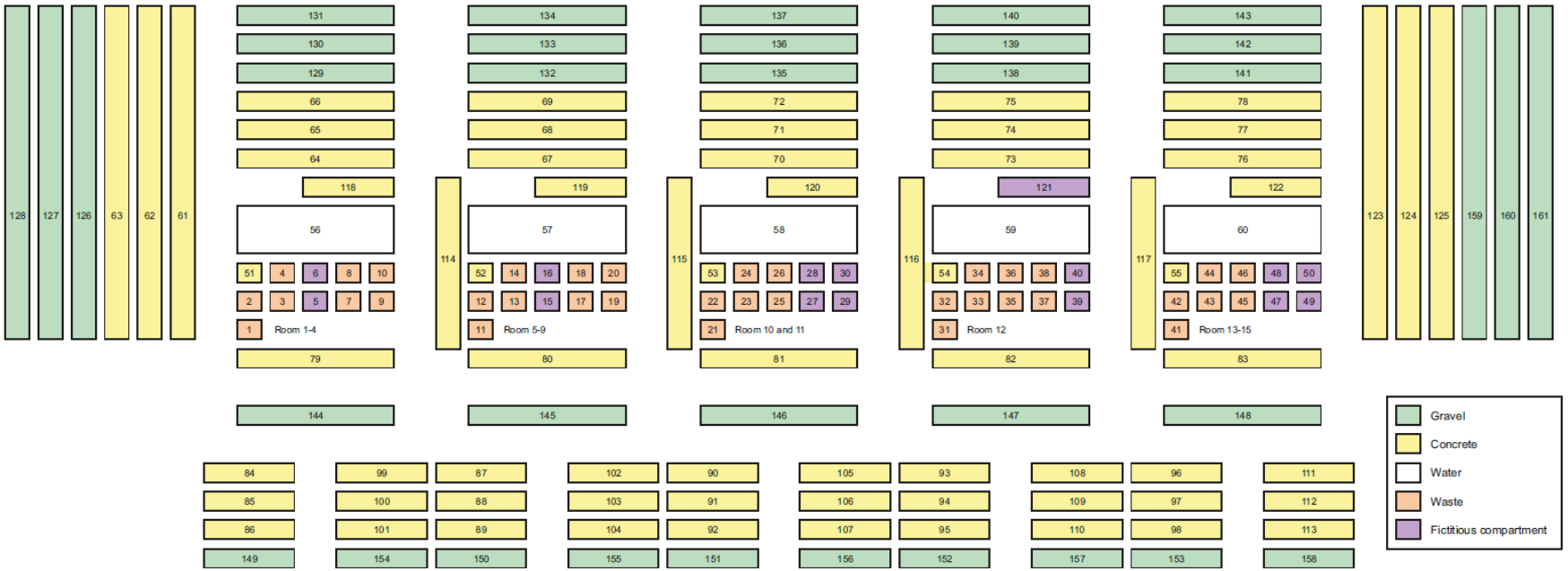
Near field model discretisation (BMA)



1-2, 11-12, 21-22, 31-32, 41-42	Waste stabilised with cement in concrete moduls
3-4, 13-14, 23-24, 33-34, 43-44	Waste stabilised with cement in steel containers
25-26, 35-36, 45-46	Waste stabilised with cement in steel drums
7-8, 17-18, 37-38	Waste stabilised with bitumen in steel containers
9-10, 19-20	Waste stabilised with bitumen in steel drums
5-6, 15-16, 27-30, 39-40, 47-50	Fictitious source terms
51-55	Walls of concrete moduls
56-60	Water inside encapsulation
61-63	Wall at short side of the structure (passage)
64-78	Ceiling of the structure
79-83	Bottom of the structure
84-98	Wall on left side of the structure
99-113	Wall on right side of the structure
114	Inner wall between room 4 and 5
115	Inner wall between room 9 and 10
116	Inner wall between room 11 and 12
117	Inner wall between room 12 and 13
118	Inner wall between room 1 and 2, 2 and 3, 3 and 4 (sink)
119	Inner wall between room 5 and 6, 6 and 7, 7 and 8, 8 and 9 (sink)
120	Inner wall between room 10 and 11 (sink)
121	Fictitious compartment (no inner wall, only one room)
122	Inner wall between room 13 and 14/15 and between room 14 and 15 (sink)
123-125	Wall at short side of the structure (loading zone)
126-128	Gravel at the end of the tunnel (passage)
129-143	Gravel at the top of the tunnel
144-148	Gravel at the bottom of the tunnel
149-153	Lateral gravel on the left side of the tunnel
154-158	Lateral gravel on the right side of the tunnel
159-161	Gravel at the end of the tunnel (loading zone)

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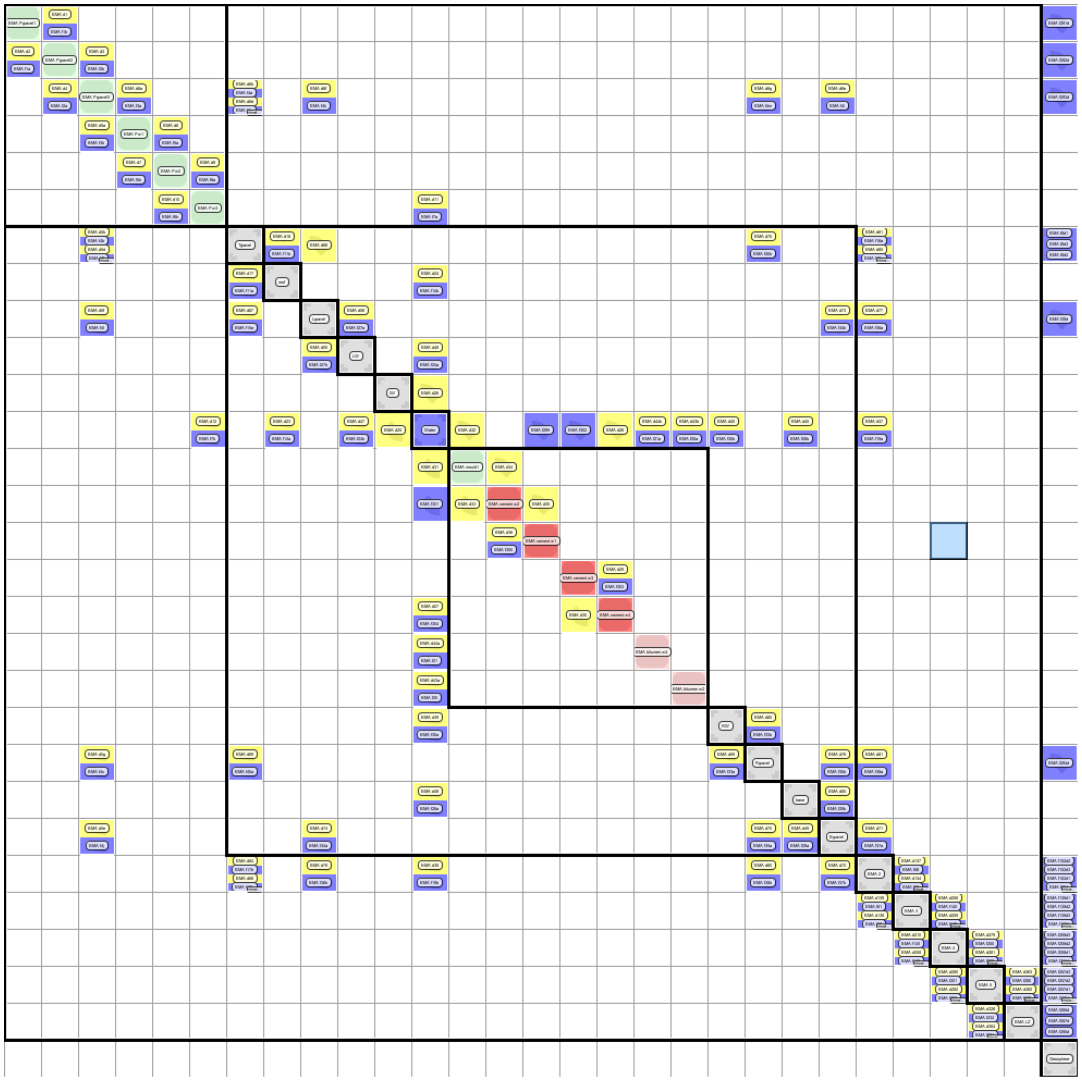
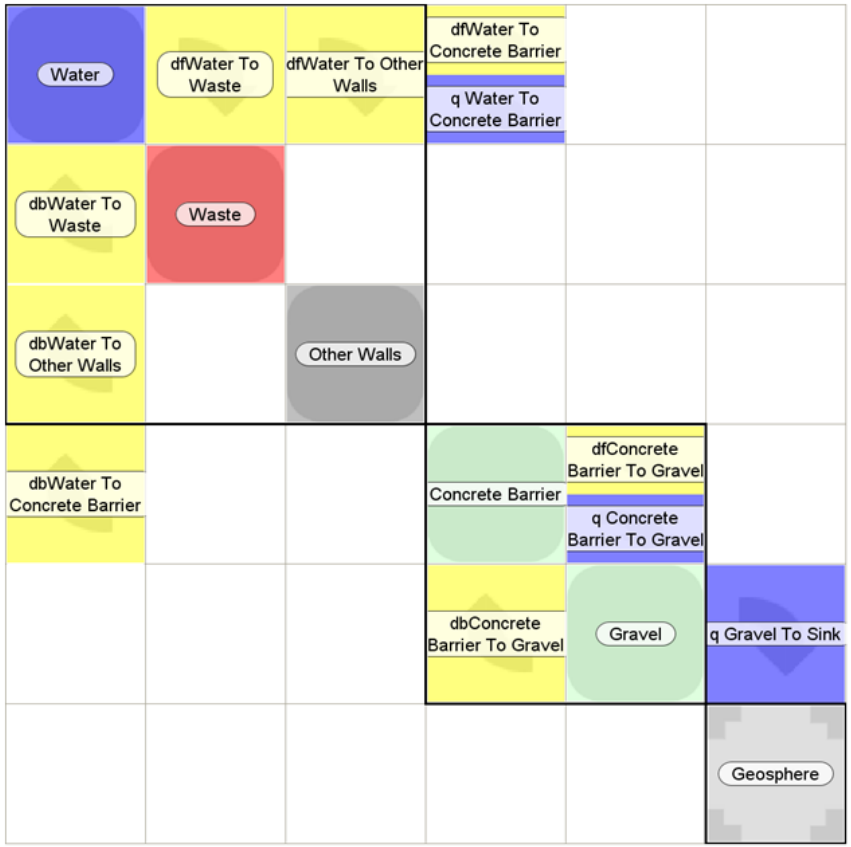
Near field model in Ecolego (BMA)



Simplified near field model (BMA)



Comparison simple between simplified and detailed near field models (BMA)

Nuclide	Max value [Bq/y]	Time for max [y]	Original max value [Bq/y]	Original time for max [y]	Ratio [-] simple/original
C-14-in	8.70E+05	5.61E+04	1.26E+06	5.61E+04	0.69
C-14-org	6.88E+07	1.00E+03	2.79E+08	1.05E+03	0.25
Cs-135	1.99E+05	5.60E+04	1.13E+05	5.60E+04	1.76
Ni-59	1.02E+08	9.10E+04	2.00E+08	9.10E+04	0.51
Pu-239	1.28E+02	9.10E+04	3.26E+02	9.10E+04	0.39
Se-79	1.47E+05	5.61E+04	1.68E+05	5.61E+04	0.88

Reactor tank disposal

Source: SKB R-04-44webb.pdf

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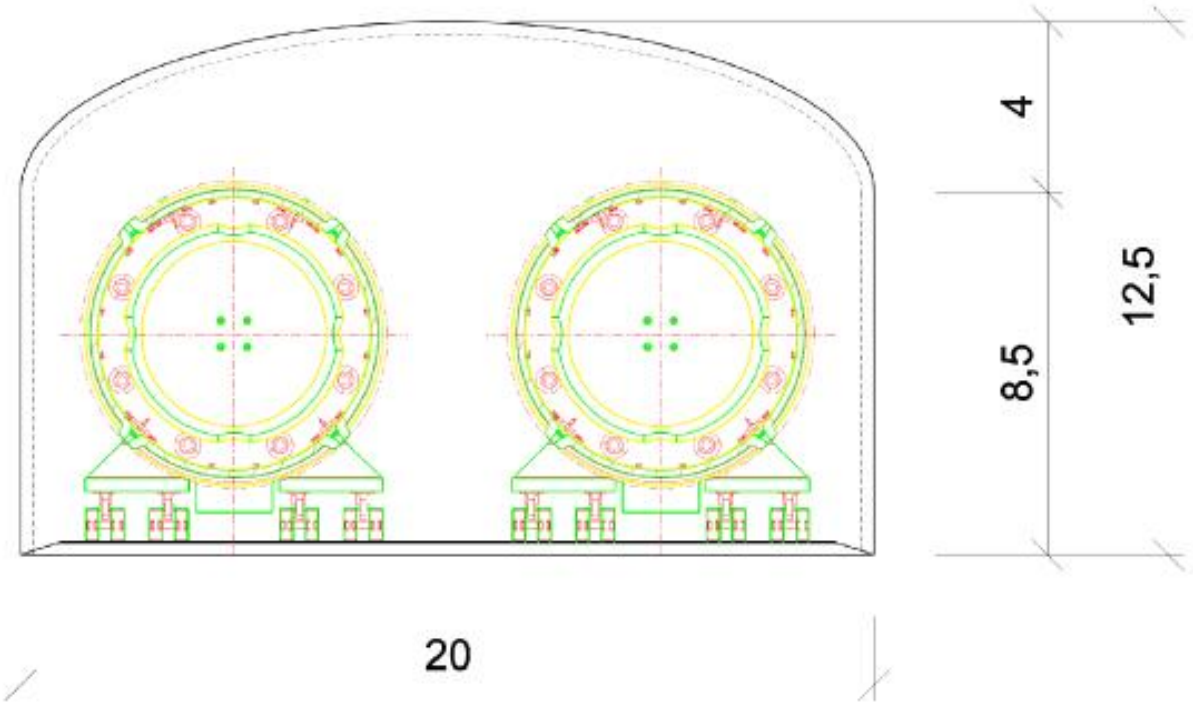
BRT for reactor tanks



Reactor tanks inventory

Nuclide	On surface [Bq]	Inside Steel [Bq]
Co-60	-	2.20E+13
Ni-63	-	4.00E+13
Ni-59	-	3.80E+11
C-14	-	4.90E+10
Cl-36	-	3.00E+07
Mo-93	-	1.40E+10
Nb-94	-	7.60E+09
Tc-99	-	2.20E+09
Pu-240	3.70E+07	-
Cm-244	1.50E+08	-
Pu-241	4.30E+09	-
Pu-239	2.30E+07	-

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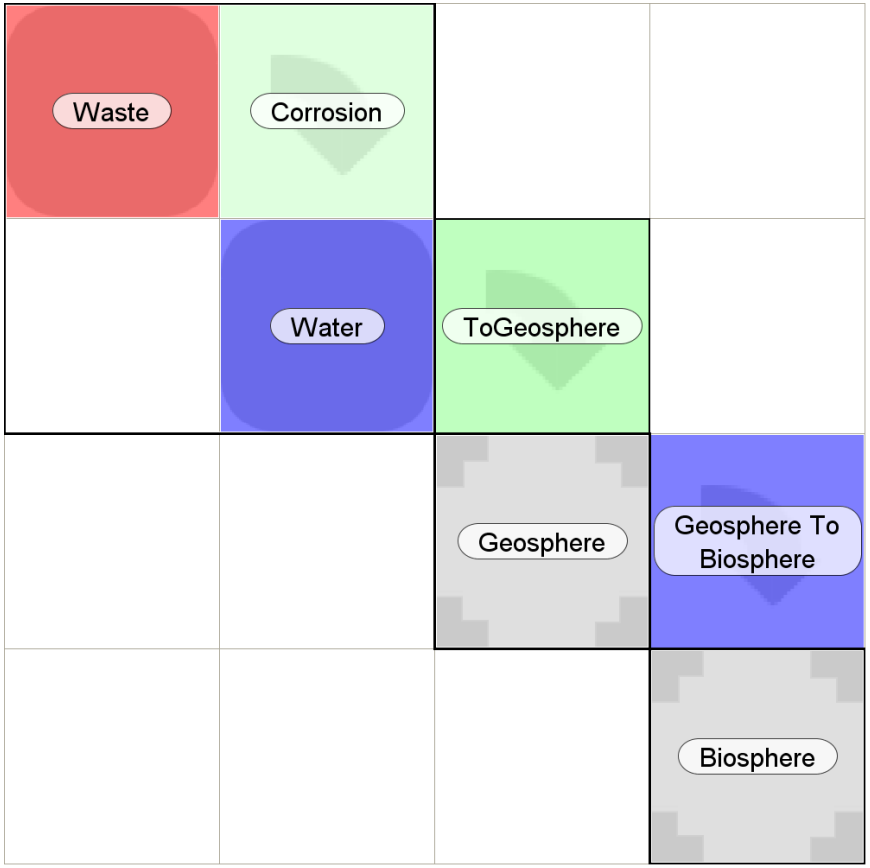
Reactor tank repository model without barriers



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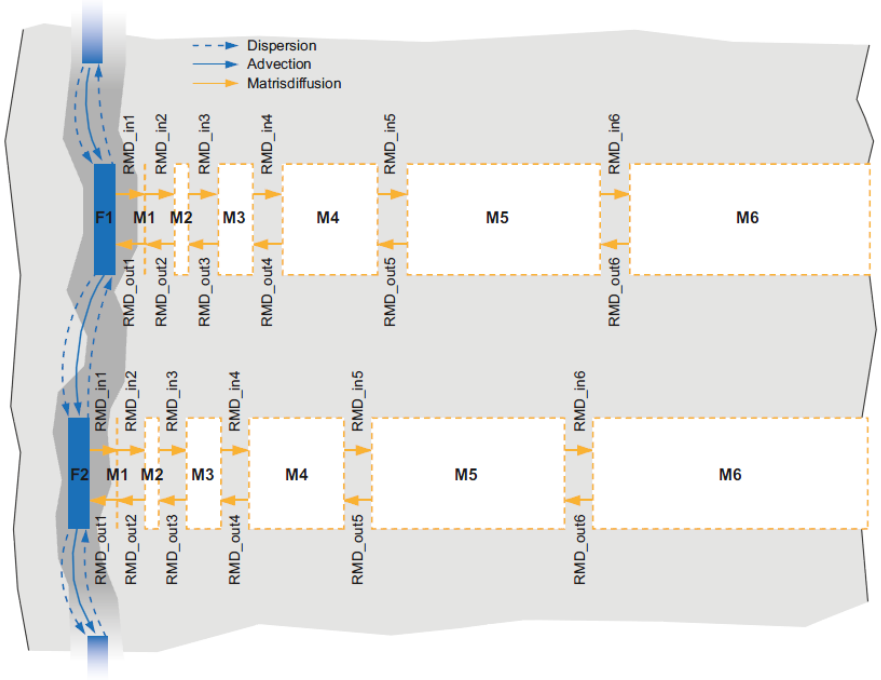
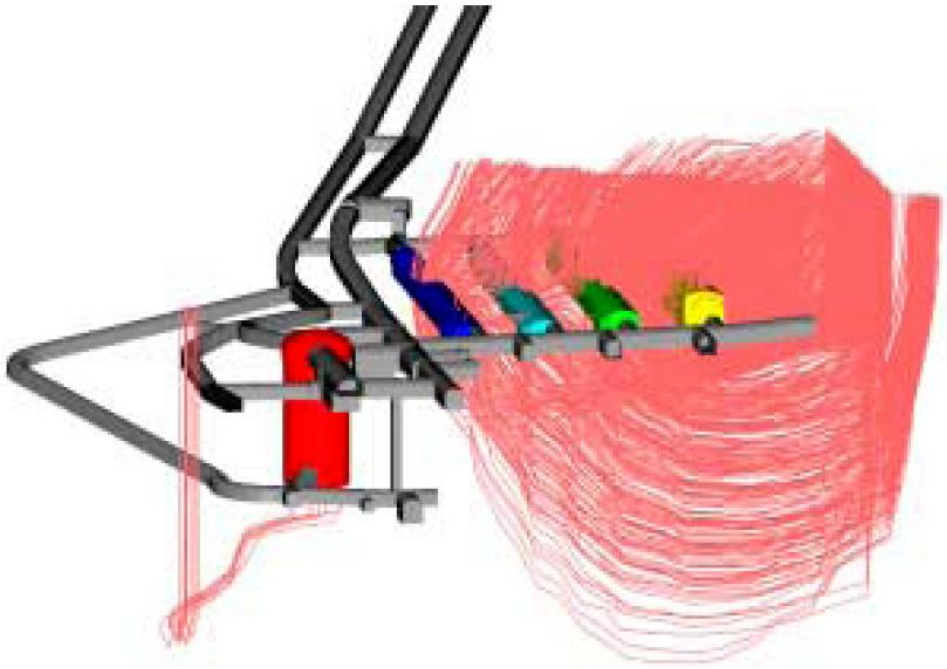
Geosphere conceptual model



- Processes
  - Advection
  - Dispersion
  - Matrix diffusion
- Parameters
  - Water travel time
  - Path length
  - Flow wetted area
  - Peclet number
  - Rock matrix properties
    - Kd, De, porosity

Geosphere process level model



Detailed particle tracking model is used to derive parameters used in a simper compartment model – system level model.

It is also used for comparisons with the system level model

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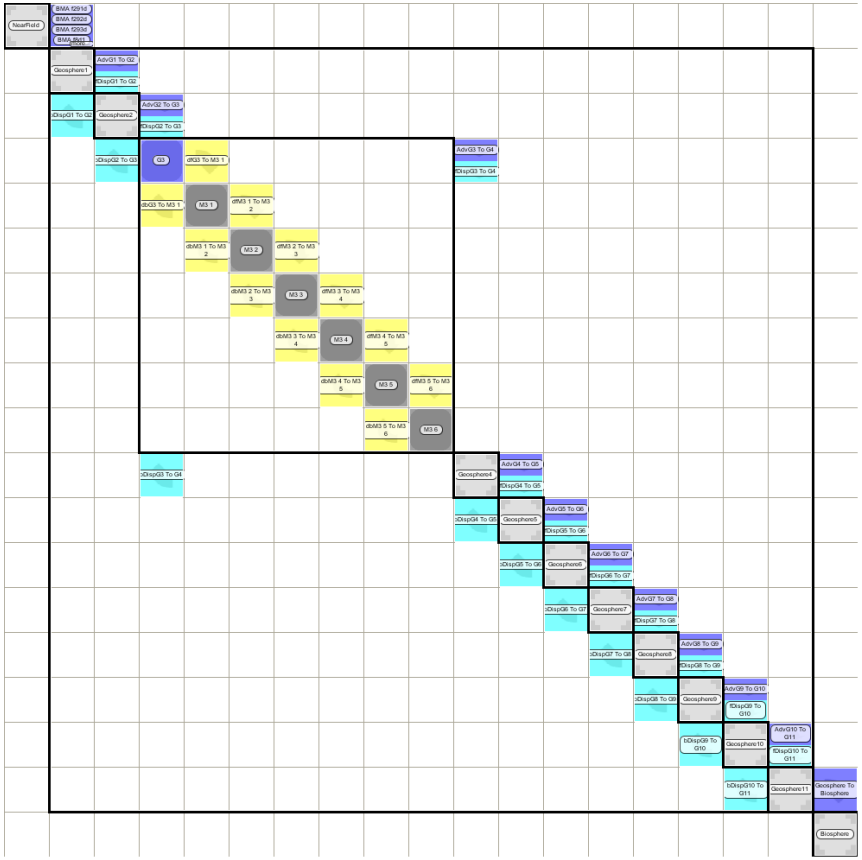
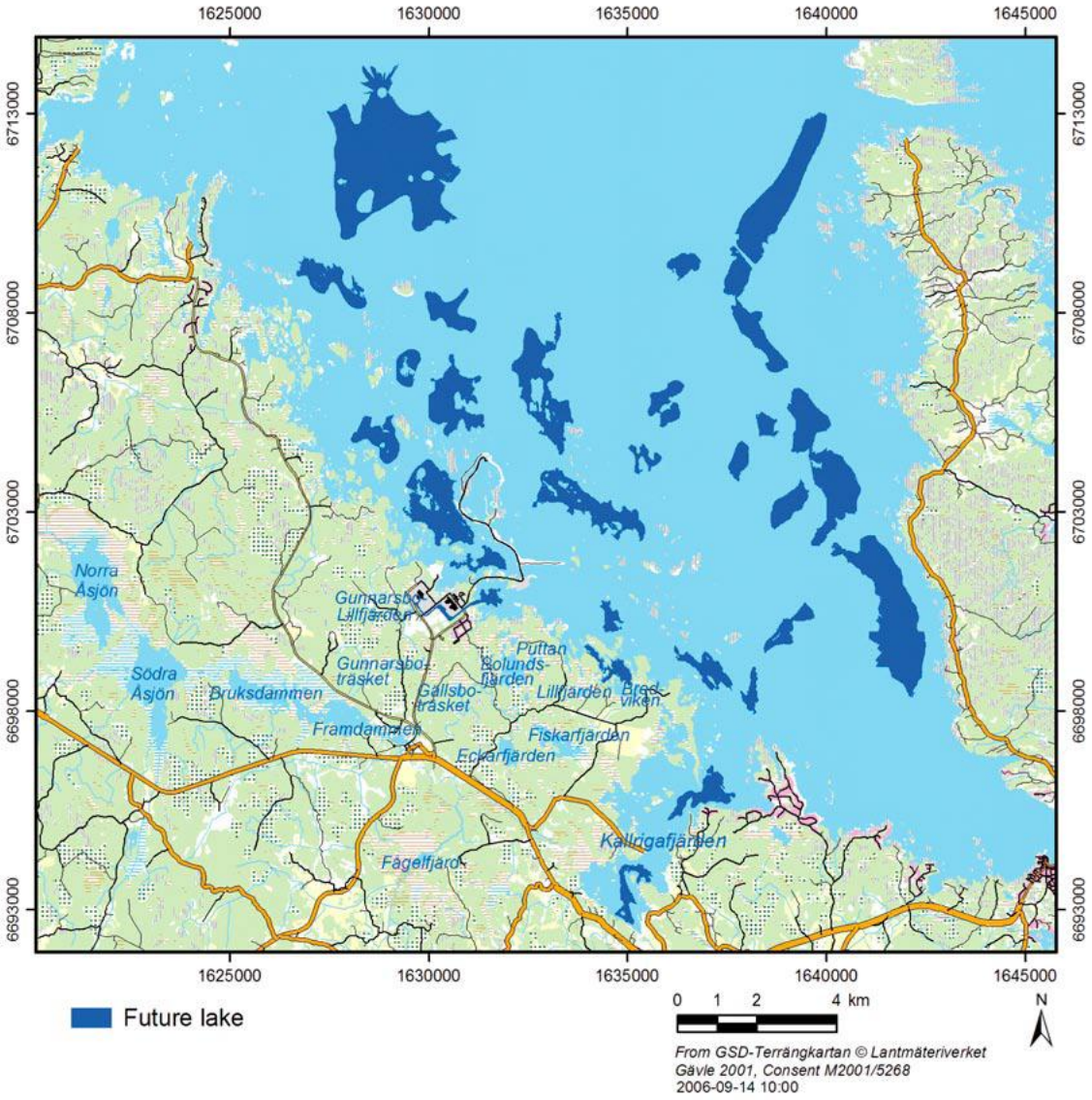
Geosphere compartment model





Present and future lakes in the potentially affected area

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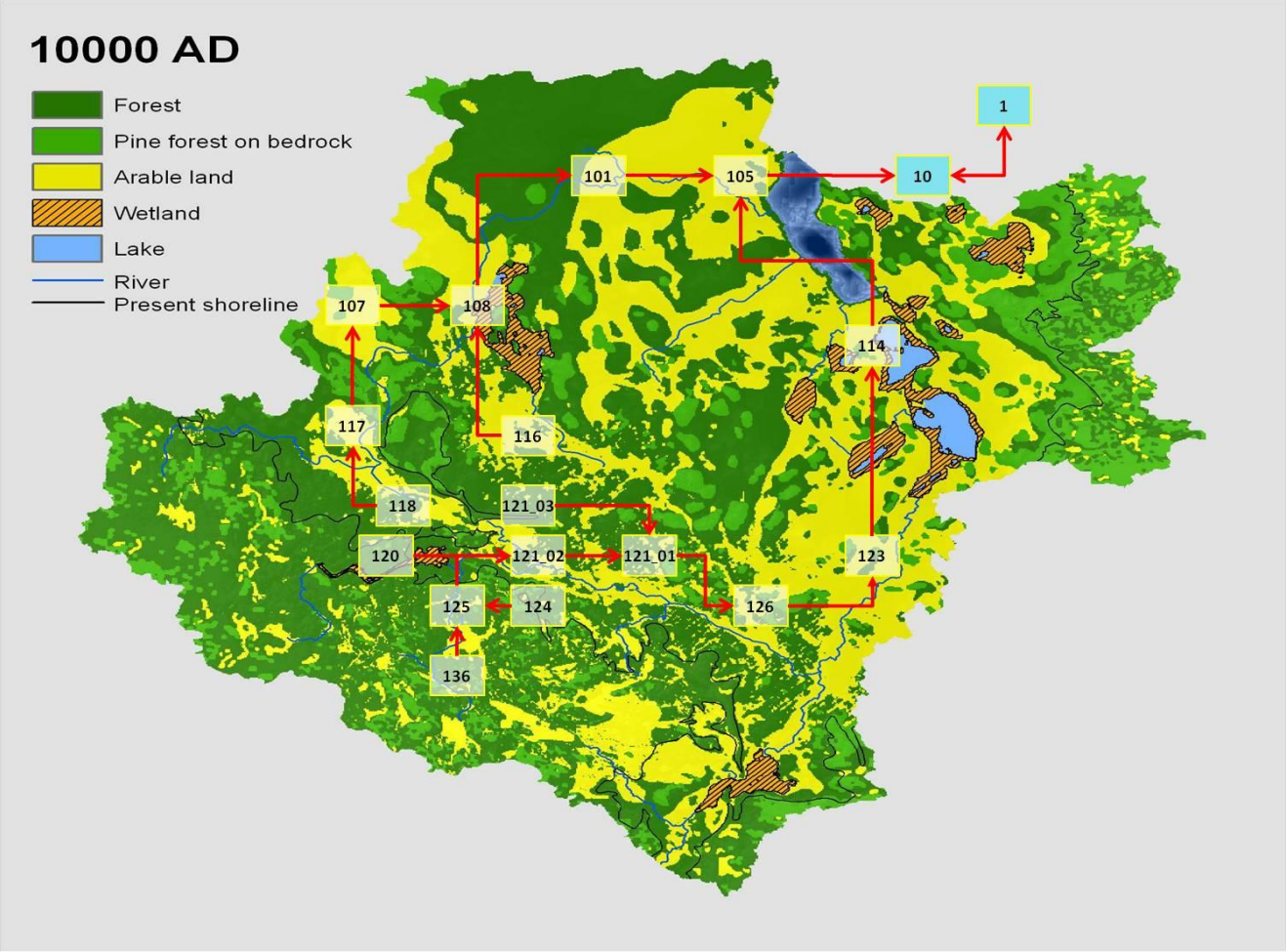
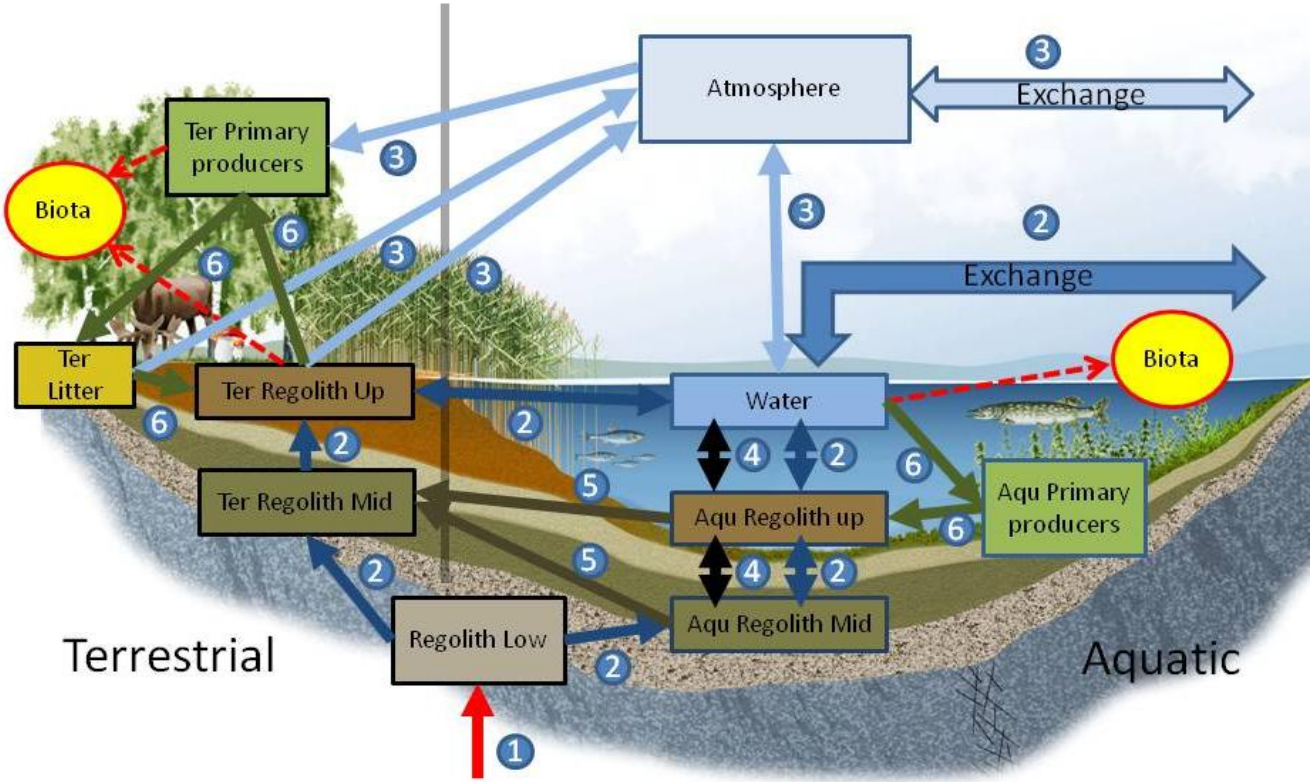
The landscape at year 10000 AD



Biosphere conceptual model for SFR



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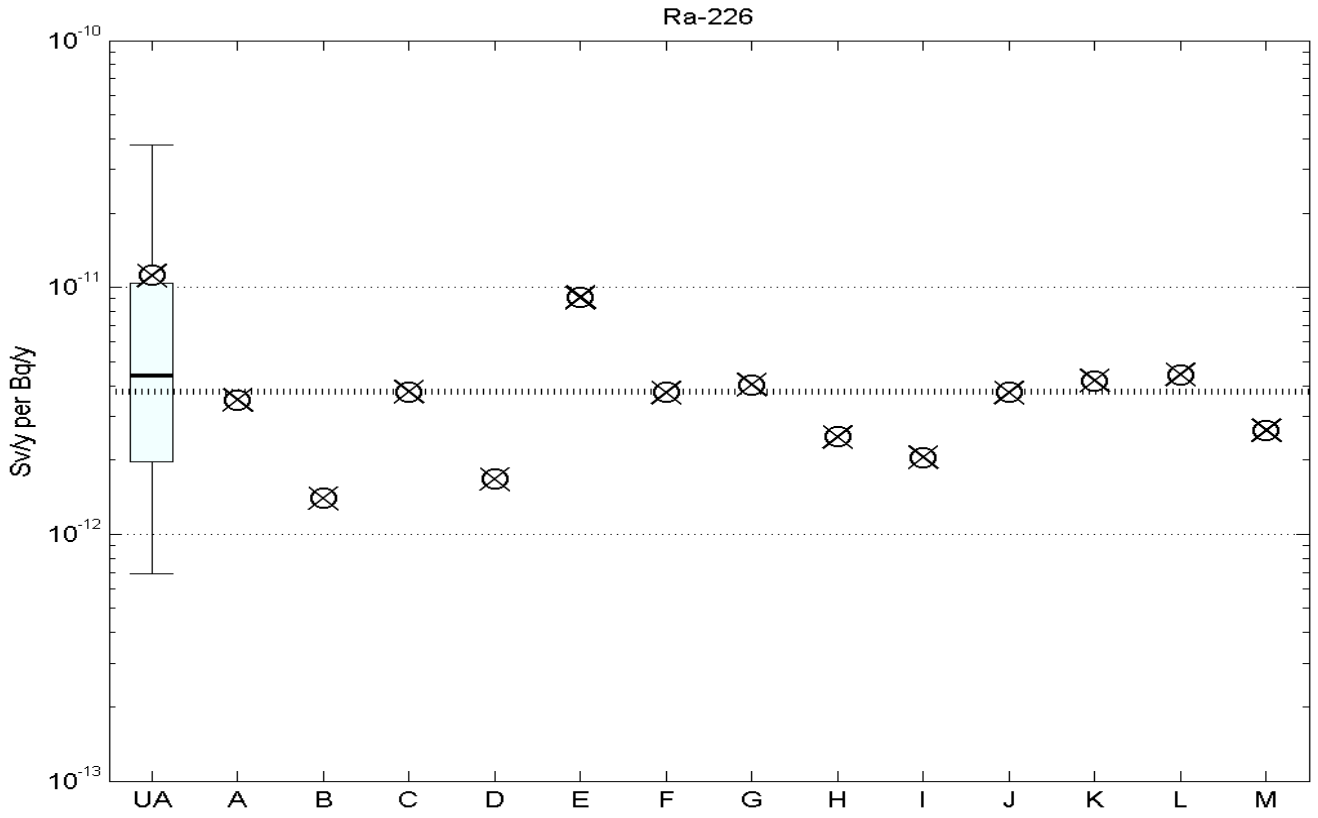
Analysis of conceptual uncertainties
Peak doses for Ra-226



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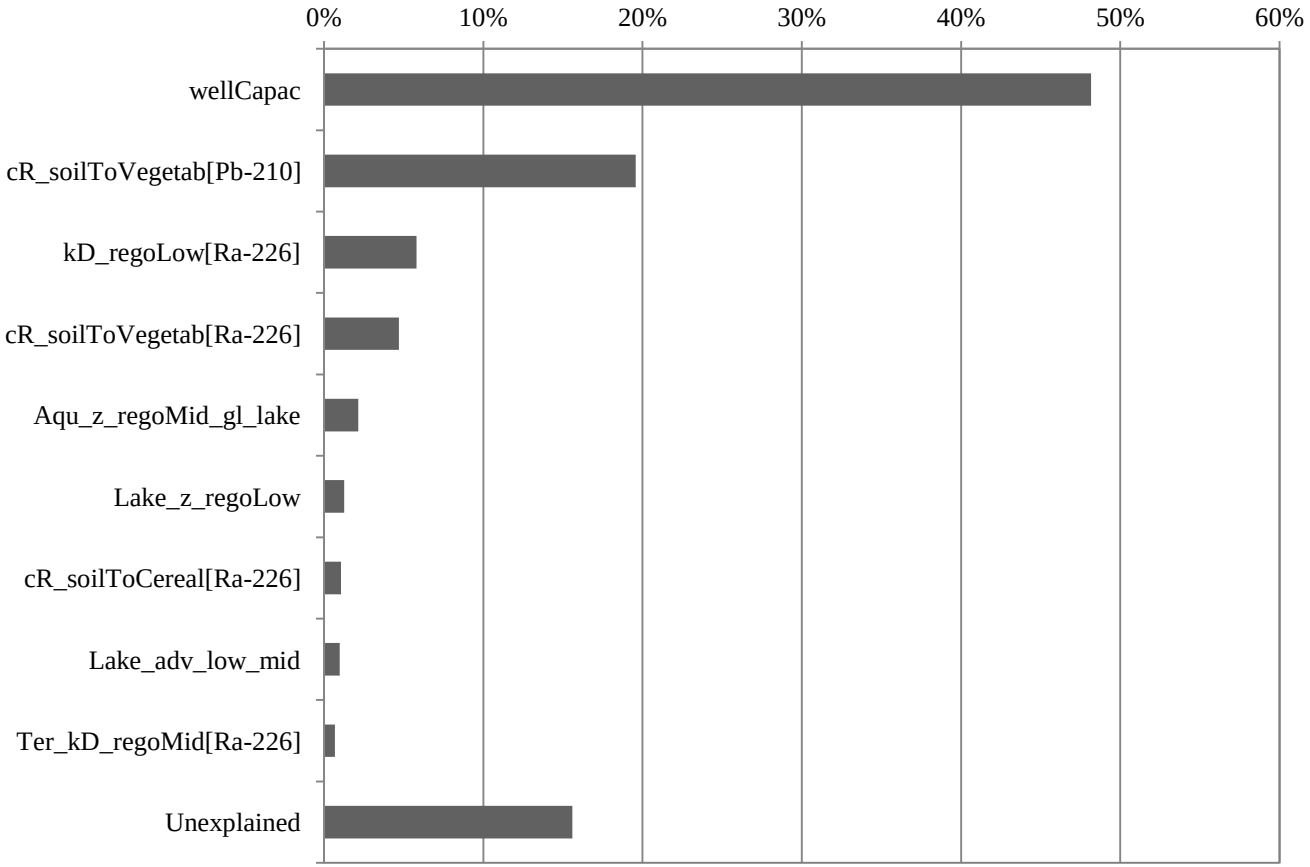
Sensitivity Analysis
Ra-226



Concluding remarks

- Conceptual models contribute to the transparency of a safety assessment and are also the focus of attention of independent reviewers.
- They are useful for designing and justifying qualitative assessments of scenarios.
- Are the basis for the development of mathematical models, which are used in quantitative assessments of scenarios.
- A systematic approach to the development and documentation of conceptual models is recommended.

Concluding remarks

- Use of several conceptual models of different level of detail is recommended.
- Combination of system and process level models in the safety assessment has proven useful and practical.
- An iterative and graded approach to the development of conceptual models is nearly a necessity.
- Uncertainty analyses of the conceptual model should be an integral part of the overall uncertainty analysis and are best performed in combination with analysis of system and parameter uncertainties.

References

- IAEA-ISAM-Vol1
- SKB reports:
  - R-01-18-web
  - R-08-13 -web
  - R-08-14-web
  - R-08-15-web
  - R2225-r2-InfFinal-6-final-draft
  - TR-10-06webb
  - TR-10-07webb-2011-10