Prospective Activities of Regulatory Safety Research and Development on Sub-Surface and Near-Surface Disposal

I. Background of Safety Policies Based on the Risk-informed Approach Concerning Sub-Surface and Near-Surface Disposals
II. Planned Concept of Sub-Surface Disposal Facility to be Assessed
III. Overview of "Guides for the Safety Assessment of Sub-Surface Disposal after the Termination of the Institutional Control Period (Draft)"
IV. Procedure of Regulation Support Research and Development on Sub-Surface Disposal
V. Major Current Regulatory Safety R&D on Sub-Surface Disposal and Key Technical Issues
VI. Prospective Activities of Regulation Support R&D in the Future

February 23, 2010
Hiroto Kawakami
Japan Nuclear Energy Safety Organization (JNES)

I. Background of Safety Policies Based on the Risk-Informed Approach Concerning Sub-Surface and Near-Surface Disposals

Safety case and FEP analysis

Compilation of results from the analysis of all factors that may affect the safety of disposal facilities and of the arguments that support safety

IAEA safety requirement "Disposal of Radioactive Waste" (SSR-5)

OECD/NEA international FEP list

Optimization of radiation protection within dose constraint and risk constraint for potential exposure

- Aggregated approach
- Dose/probability disaggregated approach

ICRP Pub81

Reactor safety goal 10-6/year

Nuclear Safety Commission "Interim Summary of Investigations and Discussions Concerning Safety Goals" (December 2003)

Risk-informed approach

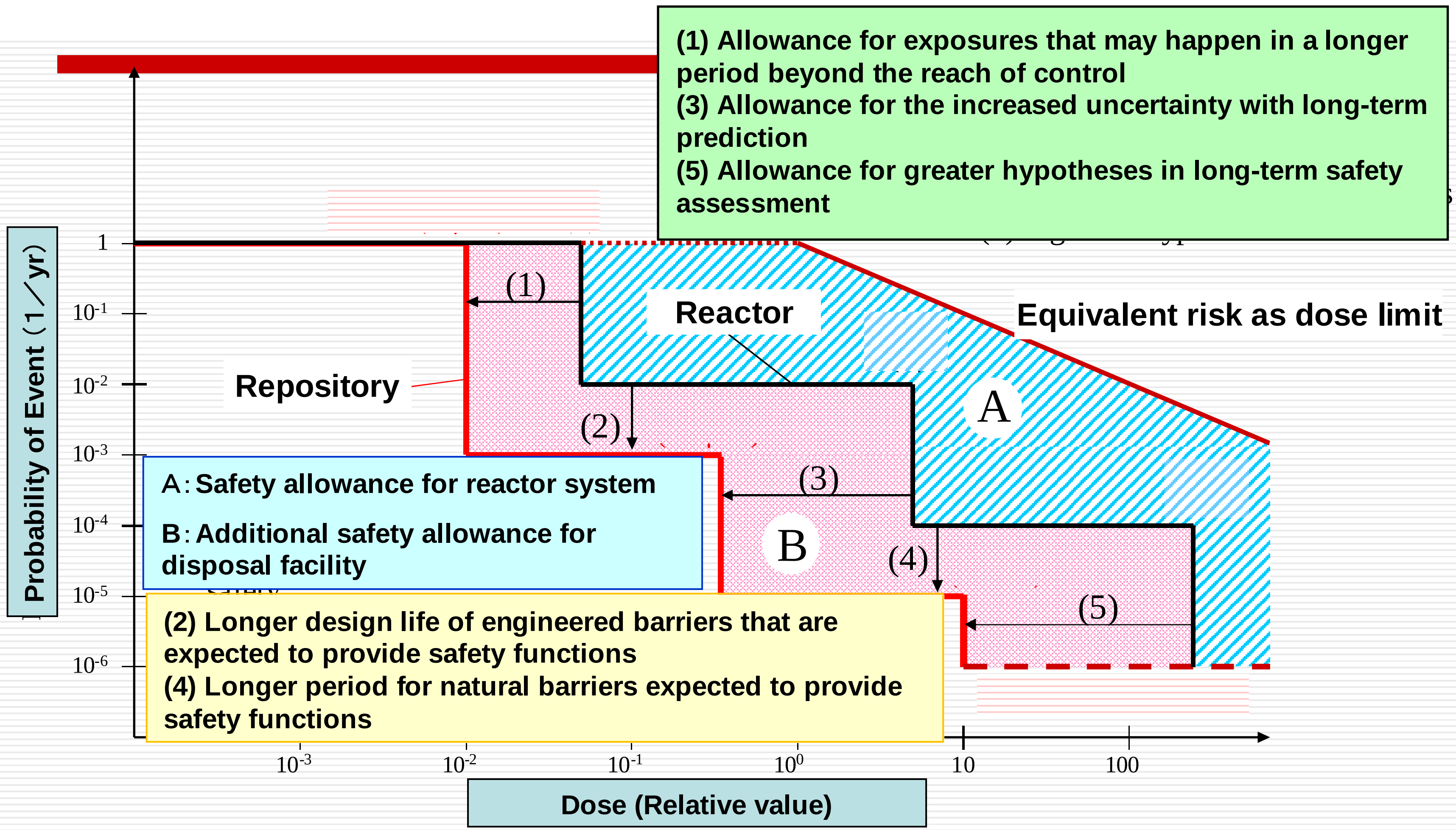
Nuclear Safety Commission "Common Important Issues of Safety Regulation on Radioactive Waste Disposal" 'June 10, 2004)

Classification of scenarios into three categories

Nuclear Safety Commission "Basic Concept of Safety Regulation on Low-Level Radioactive Waste Disposal (Interim Report)" (July 12, 2007)

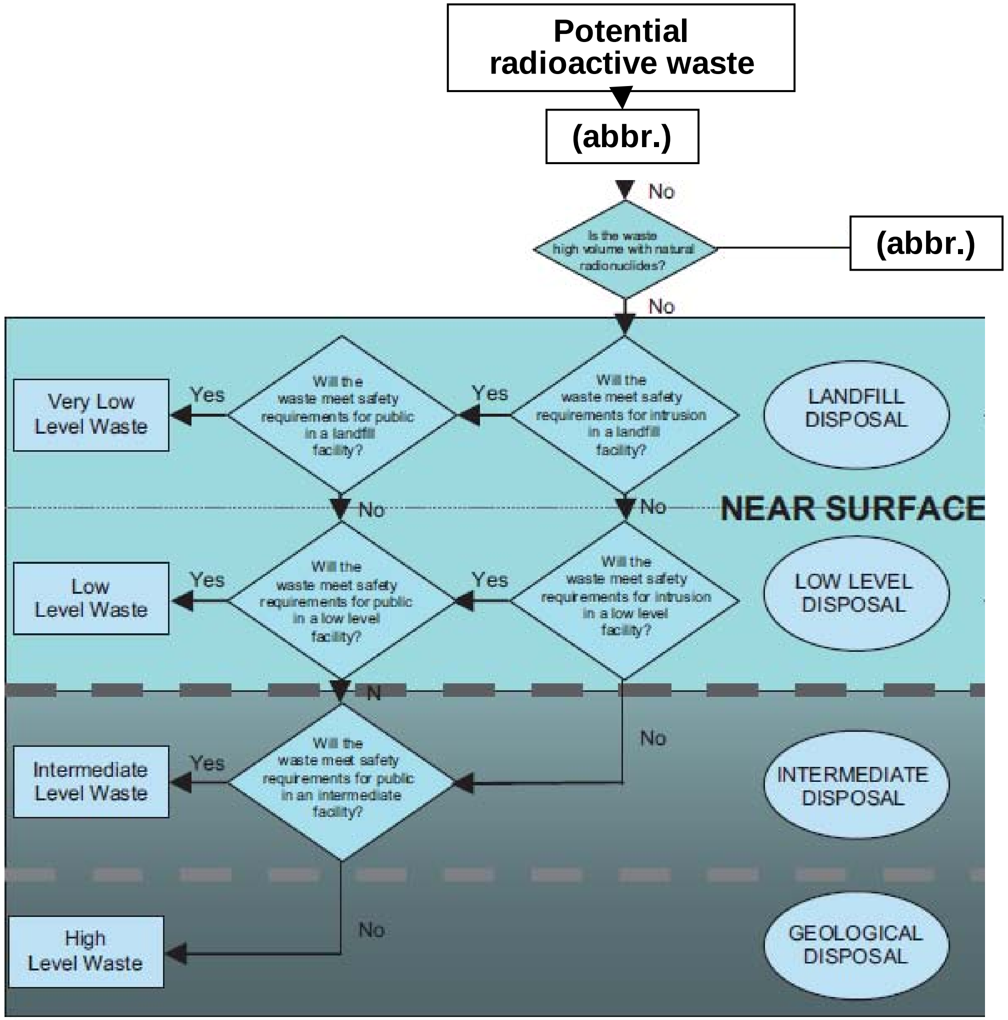
Nuclear Safety Commission Special Committee on Radioactive Waste and Decommissioning "Guides for the Safety Assessment of Sub-Surface Disposal after the Termination of the Institutional Control Period (draft)"

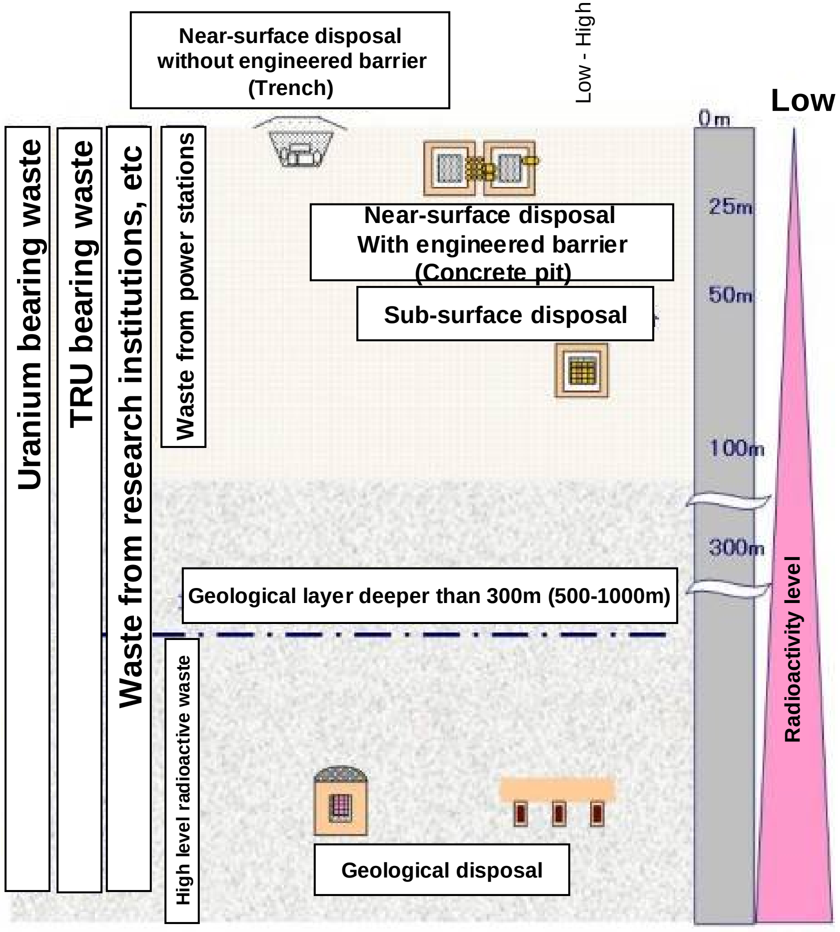
Inherent Risk of Radioactive Waste Disposal and Difference from Reactor System



Modified based on “A. Suzuki “An Overview on Radioactive Waste Disposal Regulations in Japan”

Appropriate Selection of Burial Depth and the Reduction of Human Intrusion Risk



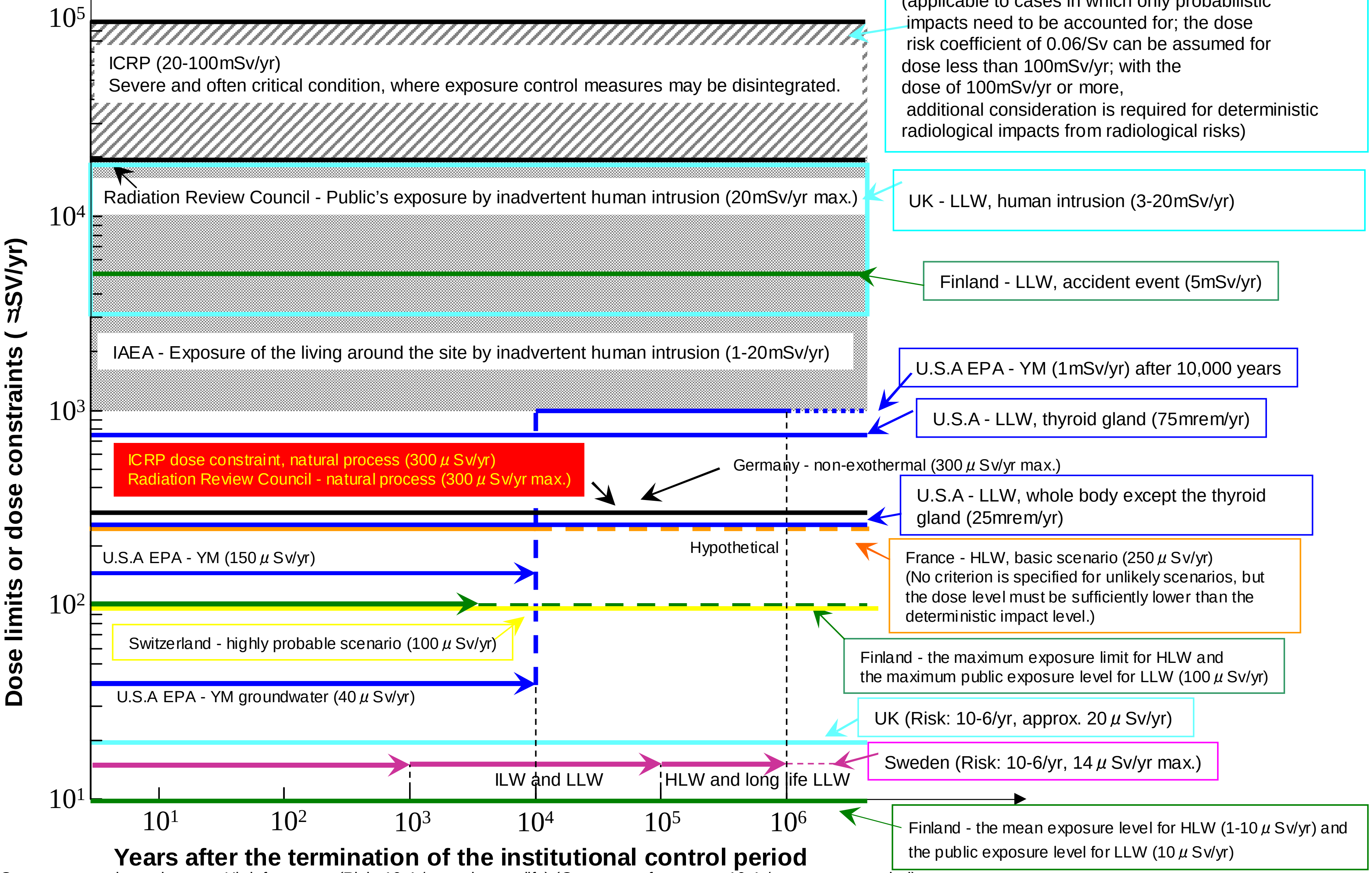


NISA web site
http://www.nisa.meti.go.jp/

The burial depth should be deeper with the increased potential hazards from the radioactive waste in order to reduce the possibility of human intrusion.

IAEA safety guideline "Classification of Radioactive Waste" (GSG-1)

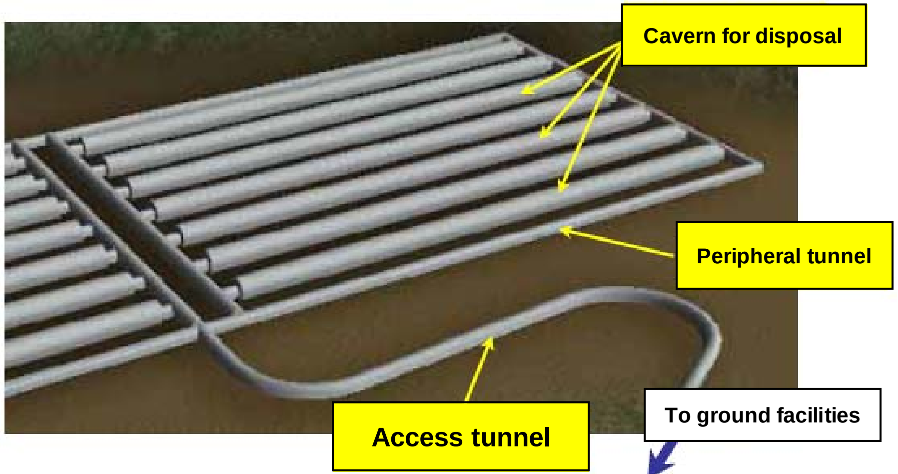
Comparison among Different Dose Criteria in the World



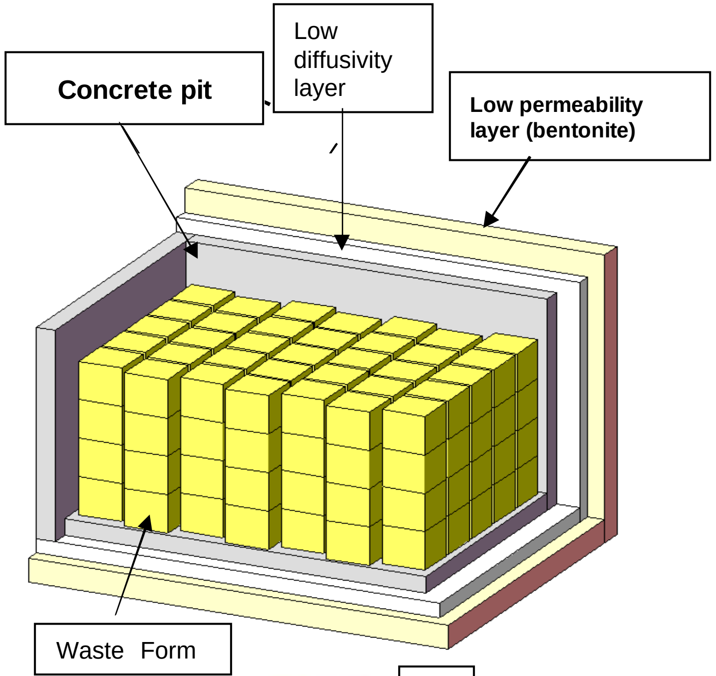
Germany – exothermal waste: High frequency (Risk: 10-4 / up to human life) (Occurrence frequency: 10-1 / assessment period)
Low frequency (Risk: 10-3 / up to human life) (Occurrence frequency: 10-2-10-1 / assessment period) Assessment period: 1 million years

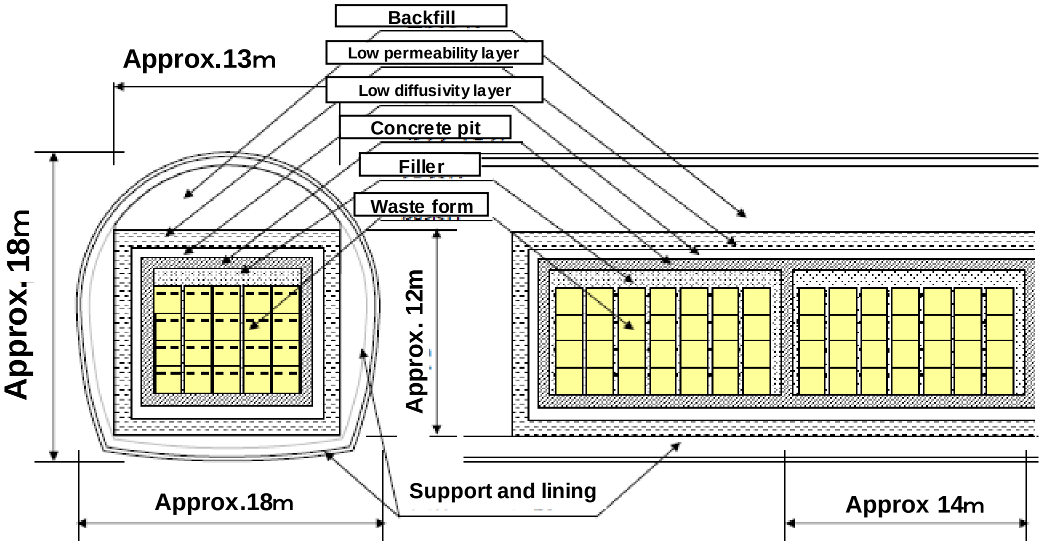
Compiled from Nuclear Safety Commission "Criteria on Radioactive Waste Disposal in Foreign Countries" (RW 24-1) with some revisions
RW: Special Committee on Radioactive Waste and Decommissioning

Ⅱ. Planned Concept of Sub-Surface Disposal Facility to be Assessed



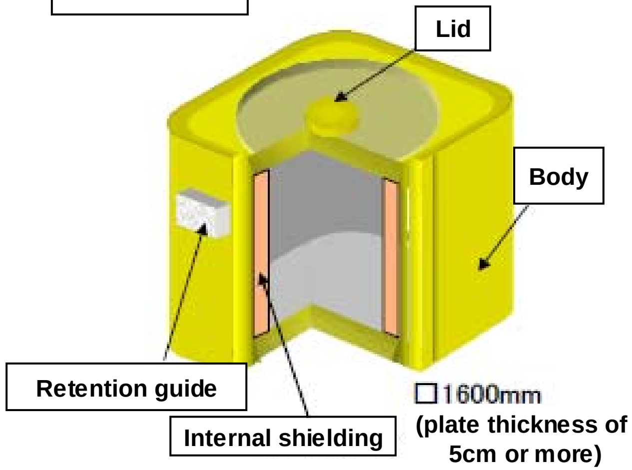
Overview of the underground structure of a waste disposal facility





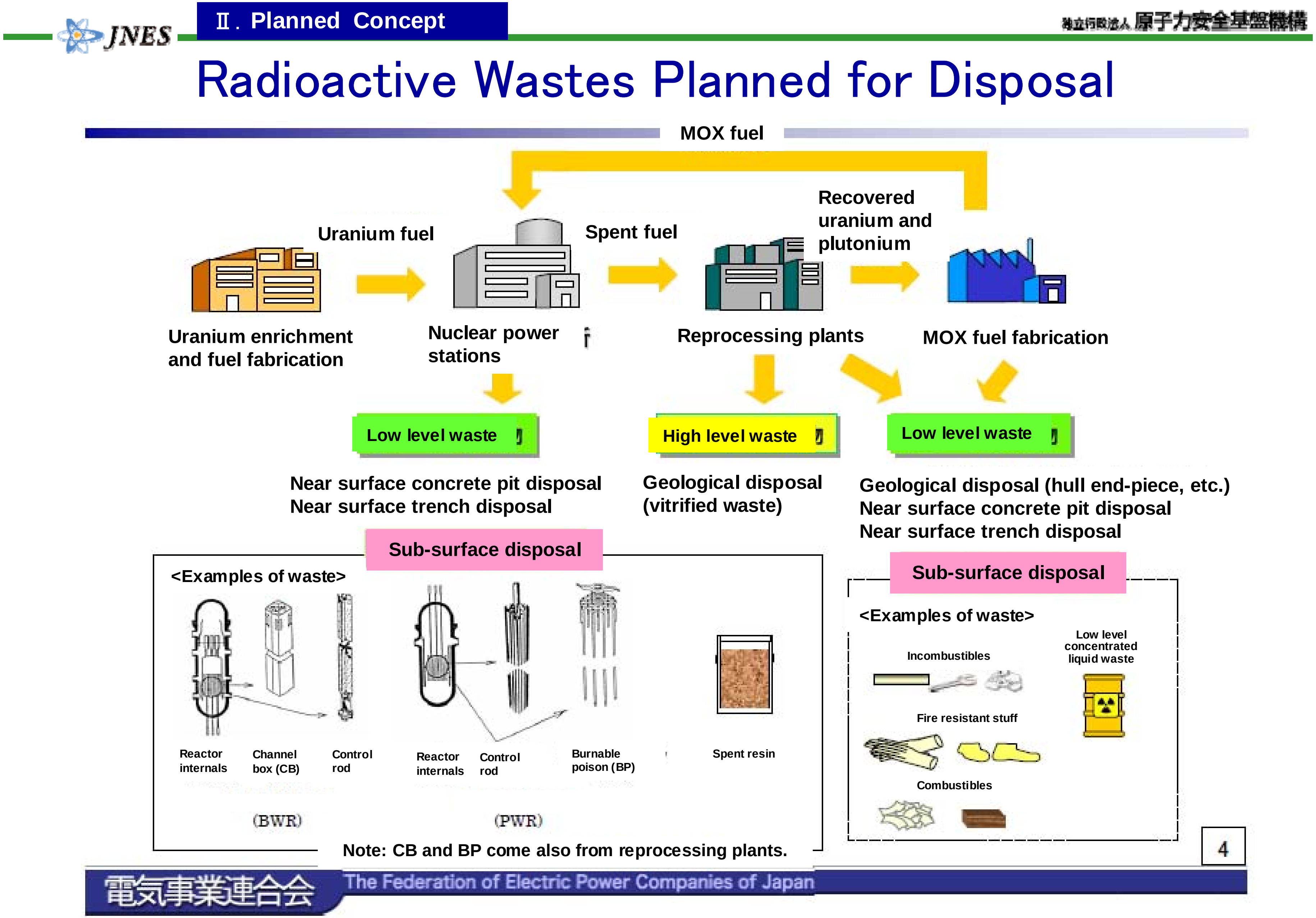
Cross-sectional view

Longitudinal sectional view



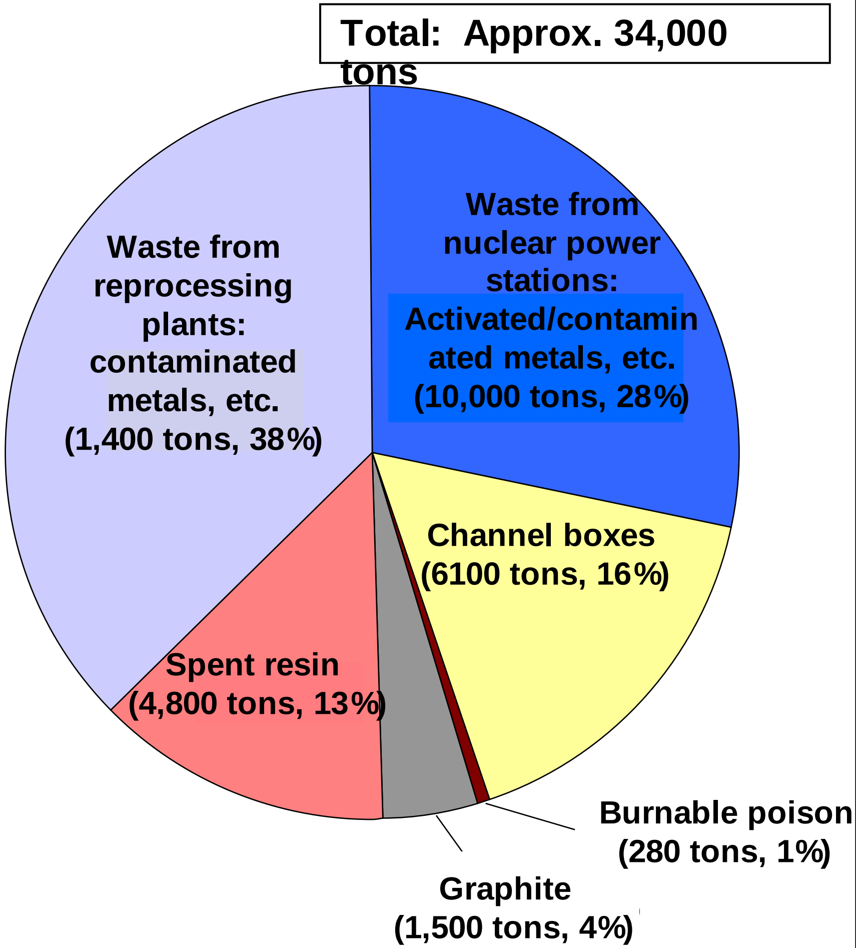
Waste form

Compiled based on information from “Report on Discussions Concerning Sub-Surface Disposal” (RW17-4)produced by the Federation of Electric Power Companies



Source: Federation of Electric Power Companies "Report on the Progress of Studies Concerning Intermediate Depth Disposal" (Document No. 17-4 on Radioactive Waste)

Quantities and Characteristics of Radioactive Waste for Sub-Surface Disposal



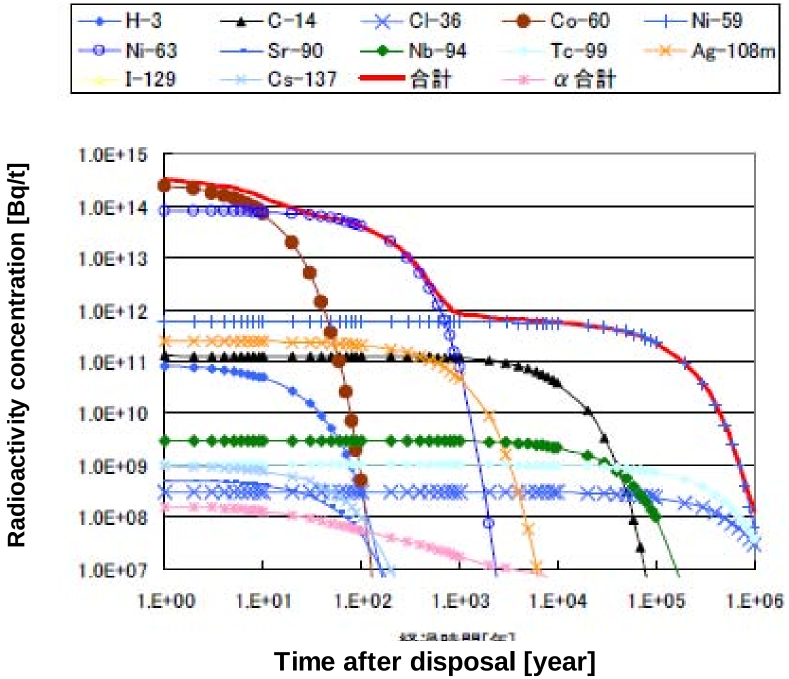
Compiled from: Federation of Electric Power Companies "Quantities and Radioactivity Concentration Levels of Waste for Intermediate Depth Disposal (C2 11-1)

Characteristics of the waste	Typical examples
Large quantity of activated metals	- Channel boxes (BWR) - Control rods (PWR control rods and hafnium control rods) - Reactor internals (BWR/PWR) - Graphite (GCR)
Inclusion of significant quantities of nuclides with a long half life	Typical examples of nuclide with a long half life: C-14: 5.73E+03 years Cl-36: 3.01E+05 years Ni-59: 7.6E+04 years Nb-94: 2.03E+04 years
Generation of large quantities of gas	- Generation of gas from the corrosion of metals - Generation of gas from the radiolysis of water - Generation of gas from the decomposition of organic matter
Inclusion of substances that may have impacts on engineered barriers	Nitrates and sulfates
Inclusion of important nuclides that are difficult to measure	Most nuclides except Co-60

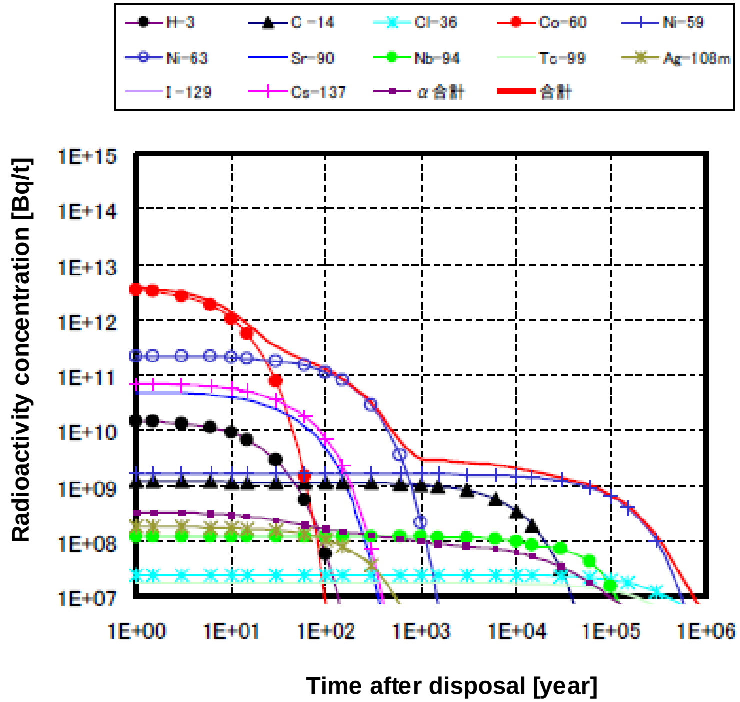
C2: Class-2 Waste Disposal Subcommittee of the Nuclear Safety Commission

Radioactivity Concentration Decay Curve of Waste in a Sub-Surface Disposal Facility

Operational waste from power stations (activated metal)



Waste from JNFL



Waste for sub-surface disposal contains significant quantities of nuclides with a long half life. The verification of the safety of sub-surface disposal facilities, therefore, requires the safety assessment over a long period.

It is important that the safety assessment should address the impacts from geological uplift, erosion and sea level change if such phenomena are likely to take place around the site in a long term.

Source: Federation of Electric Power Companies “Report on the Progress of Studies Concerning Sub-Surface Disposal” (Document No. 17-4 on Radioactive Waste)

Overview of "Guides for the Safety Assessment of Sub-Surface Disposal after the Termination of the Institutional Control Period (Draft)"

- Chapter 1 - Introduction
- Chapter 2 - Setup of Conditions for Long-Term Evolution Concerning the Geological Environment
  - → Chapter 3 – Setup of Conditions for Biosphere in the Future
    - → Chapter 4 - Setup of Conditions for the Disposal Facilities
      - → Chapter 5 – Setup of Likely Scenarios
        - → Likely scenarios for groundwater
        - → Likely scenarios for gas migration
        - → Likely scenarios for land use
      - → Chapter 6 – Setup of Less-likely Scenarios (follows Chapter 5)
        - → Less-likely scenarios for groundwater
        - → Less-likely scenarios for gas migration
        - → Less-likely scenarios for land use
      - → Chapter 7 – Setup of Rare Natural Event Scenarios
      - → Chapter 8 – Setup of Inadvertent Human Intrusion Scenarios
      - → Chapter 9 – Guides for the Termination of the Institutional Control Period
- Chapter 10 - Conclusion

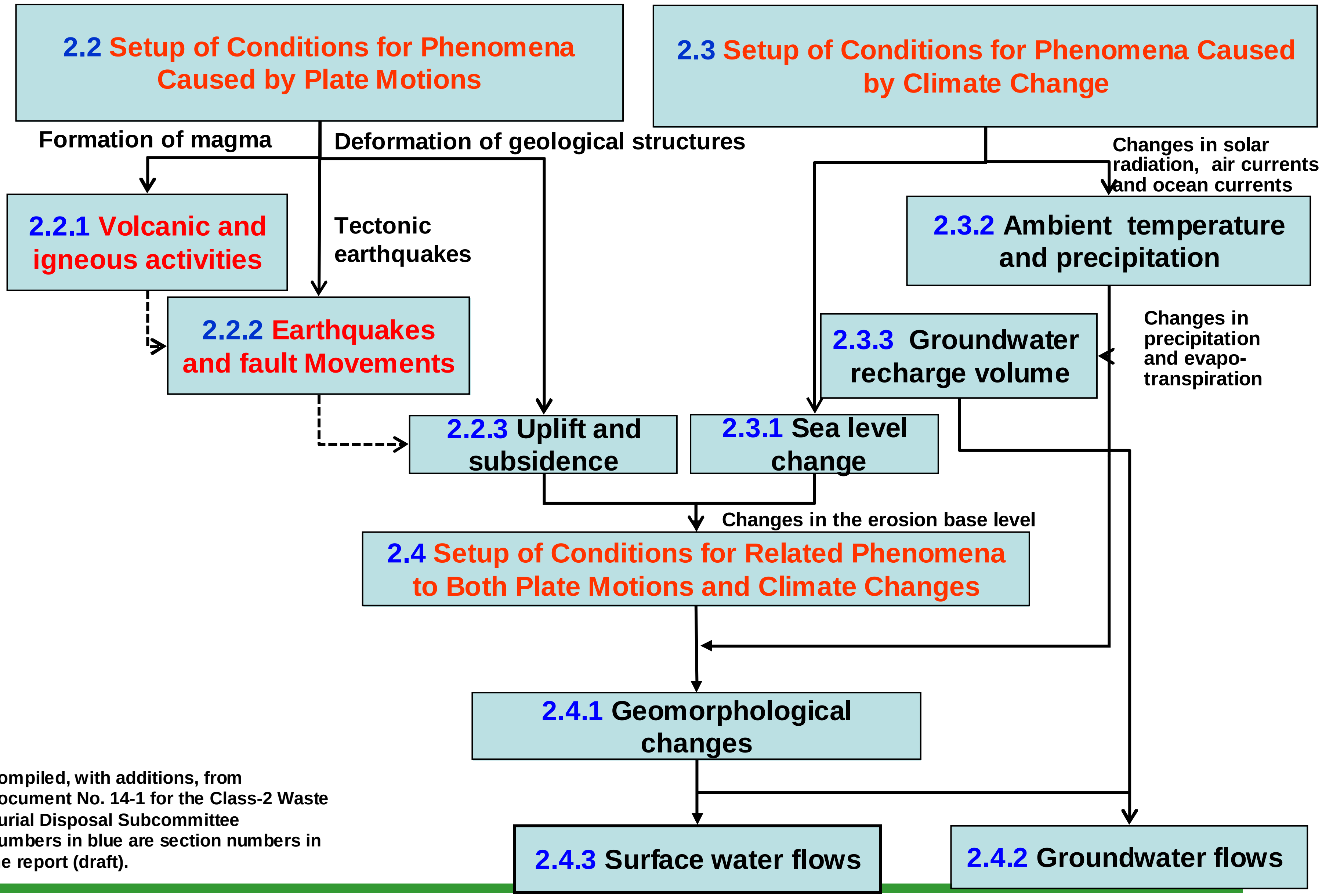
Classification of Safety Assessment Scenarios and their Assessment Objectives

Scenario category	Assessment objective	Standard dose value (Chapter 9)
Likely scenarios **(Chapter 5)**	Scenarios that address highly probable, normally expected events These scenarios account for a series of changes that are reasonably expected to take place in the repository system and exposure pathways, or affect the characteristics thereof, in the future based on the evaluation of conditions in the past and present. These scenarios are used for assessing how well the basic design concept and policy for the repository system are configured to control the dose, arising from such changes, as low as possible reasonably achievable.	10 μ Sv／yr
Less-likely scenarios **(Chapter 6)**	Scenarios that address variations that are relatively improbable but are important in the context of safety assessment These scenarios are used for assessing how well the repository system design is configured to address various uncertainties. General uncertainties in safety assessment, including uncertainties concerning properties of the geological environment, are addressed by these less-likely scenarios.	300 μ Sv／yr
Rare natural event scenarios **(Chapter 7)**	Scenarios that address highly improbable, natural phenomena Even after including the scenarios that address relatively improbable events, there remain some uncertainties. Rare natural vent scenarios are used for verifying that no additional special measure for radiation protection is deemed to be required even after giving attention to such remaining uncertainties	10mSv／yr～100mSv／yr
Inadvertent human intrusion scenarios **(Chapter 8)**	These scenarios address inadvertent human intrusion events. These scenarios are used to verify that adequate measures are taken to reduce the possibility of human intrusion and to control the exposure dose as low as reasonably achievable. These scenarios are also used to verify that no additional special measure for radiation protection is deemed to be required even after choosing a conservative assessment approach.	Residents: 1mSv／yr～10mSv／yr Intruders -defined individual intruders (e.g. workers): 10mSv／yr～100mSv／yr

(Yellow box) **The distinction between likely and less-likely scenarios is as reported in Nuclear Safety Commission "Basic Concept of Safety Regulation on Low-Level Radioactive Waste Disposal (Interim Report)" (July 12, 2007).**

(Green box) **The "human intrusion and rare events scenario " in the above-mentioned interim report is now classified further into "rare natural events" and "inadvertent human intrusion scenarios"**

Chapter 2 - Setup of Conditions for Long-Term Evolution Concerning the Geological Environment



Compiled, with additions, from Document No. 14-1 for the Class-2 Waste Burial Disposal Subcommittee
Numbers in blue are section numbers in the report (draft).

Chapter 3 - Setup of Conditions for Biosphere in the Future

Stylization of Biosphere based on IAEA International Co-ordinated Research Project BIOMASS

Principal Component
Climate and atmosphere
Geographical extent
Location
Topography
Human activity
Near surface lithostratigraphy
Water bodies
Biota

Step1

Review Assessment Context

Biosphere system pre-defined by explicit legislation or guidance?

- No → Identify and justify primary components of biosphere system(s)
- Yes → Describe pre-defined biosphere system (s)

Step2

Biosphere system change to be considered?

- Describe constant biosphere system (s)
- Identify and justify selection of mechanisms causing change → Identify potential impacts on the biosphere system → Identify qualitatively different possible futures

Step3

Select approach to represent biosphere system change

- Non-sequential: Select appropriate biosphere systems → Describe alternative non-sequential biosphere systems
- Sequential: Select appropriate biosphere systems and transitions → Describe sequential biosphere systems

Stylization of exposure pathways in the case of inadvertent human intrusion:
(1) For residents around the site (exposure pathways do not differ from the case of natural migration)
(2) For individual intruders (to be defined specifically)

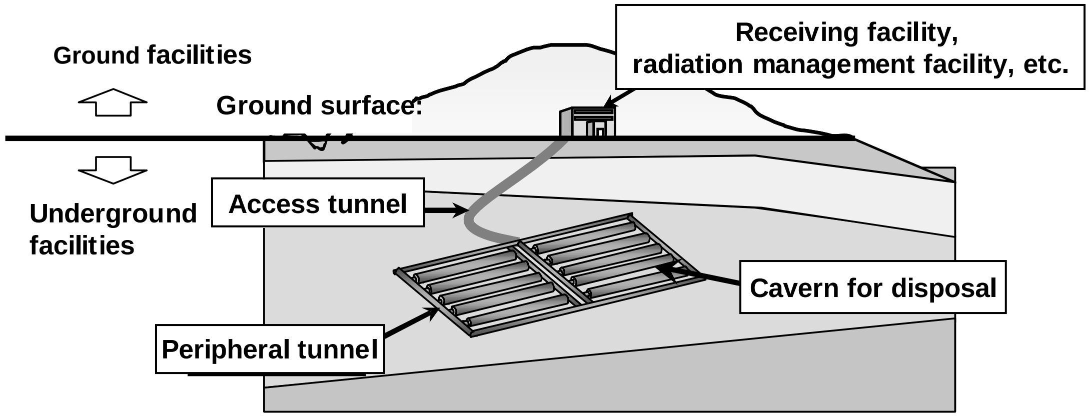
Stylization of exposure pathways in the case of natural events:
(1) Pathways of exposure by the use of water from river water, etc. (lake water, river water or stream water)
(2) Pathways of exposure by land use (riverside area, terrain covered with sediments from river, dried lake bed, land surface near the uplifted repository, etc.)
- Pathways of exposure by land use (by inhabitation)
- Pathways of exposure by land use (by construction)

IAEA「"Reference Biospheres" for solid radioactive waste disposal Report of BIOMASS Theme 1 of the BIOsphere Modelling and ASSessment (BIOMASS) Programme」(IAEA-BIOMASS、July 2003)

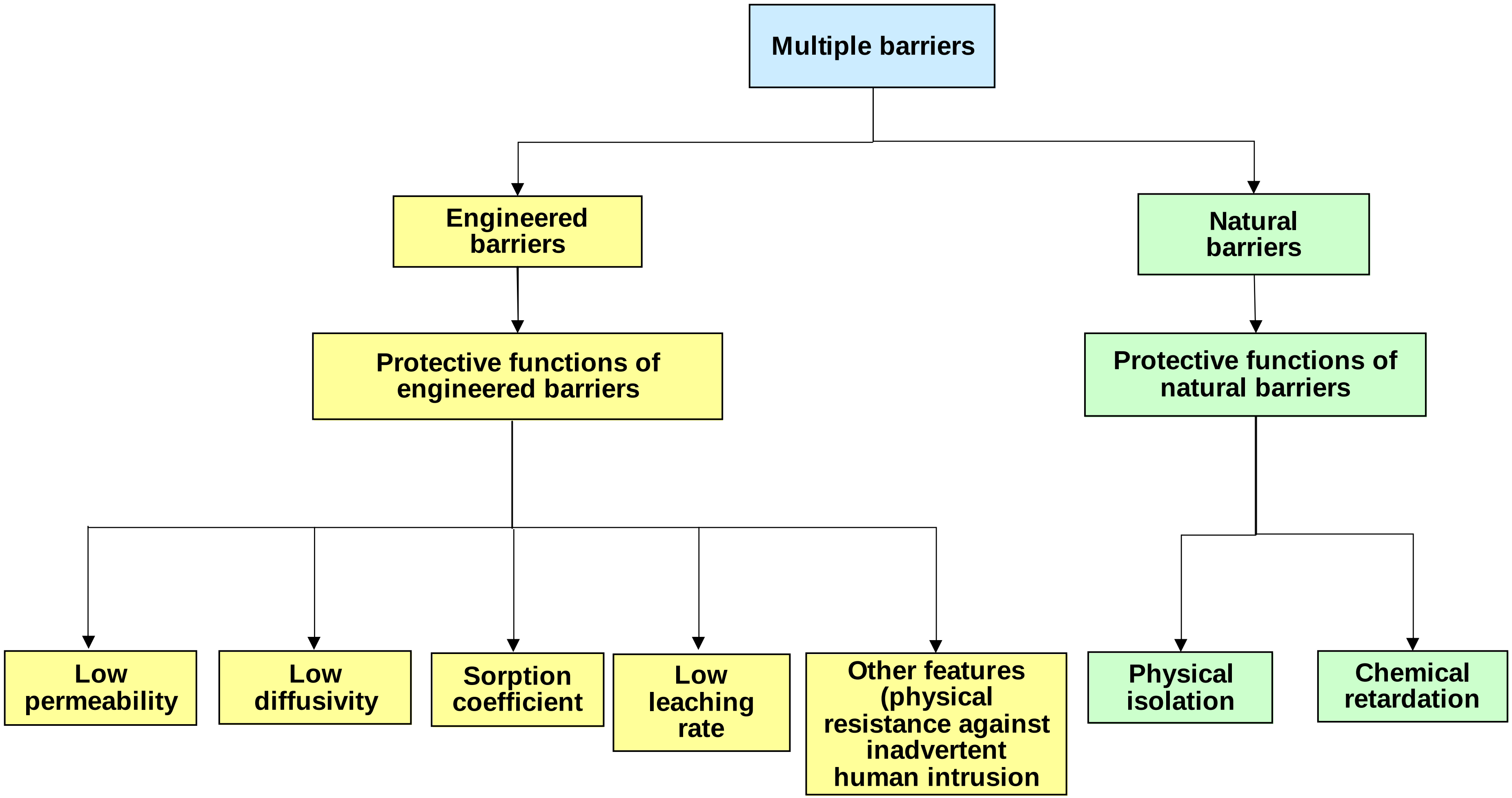
Chapter 4 - Setup of Conditions for the Disposal Facilities
Structures and Components of Disposal Facilities

An asterisk (*) identifies metal-containing components.

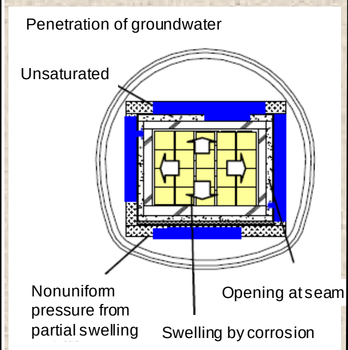
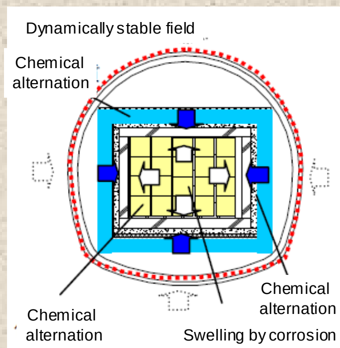
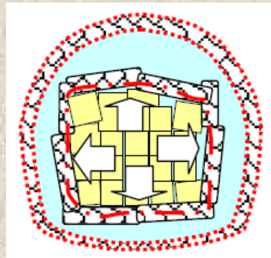
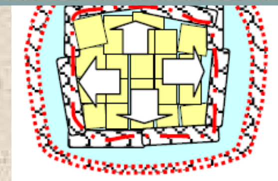
- Disposal Facility
  - Ground facilities
    - Receiving facility, etc.
  - Underground facilities
    - Access and peripheral tunnels
      - Support and lining (*)
      - Backfill
      - Plug
    - Cavern for disposal
      - Bentonite component(s)
        - Low permeability layer
        - Cavity filler
      - Cement component(s)
        - Low diffusivity layer
        - Concrete pit (*)
        - Compartment filler
      - Waste Package
        - Waste container (*)
        - Waste Form (*)
      - Support and lining (*)



Concepts of Multiple Barrier Structures of Sub-Surface Disposal Facilities and Their Protective Functions



Guides for the Setup of Conditions of Disposal Facilities for Different Time Periods

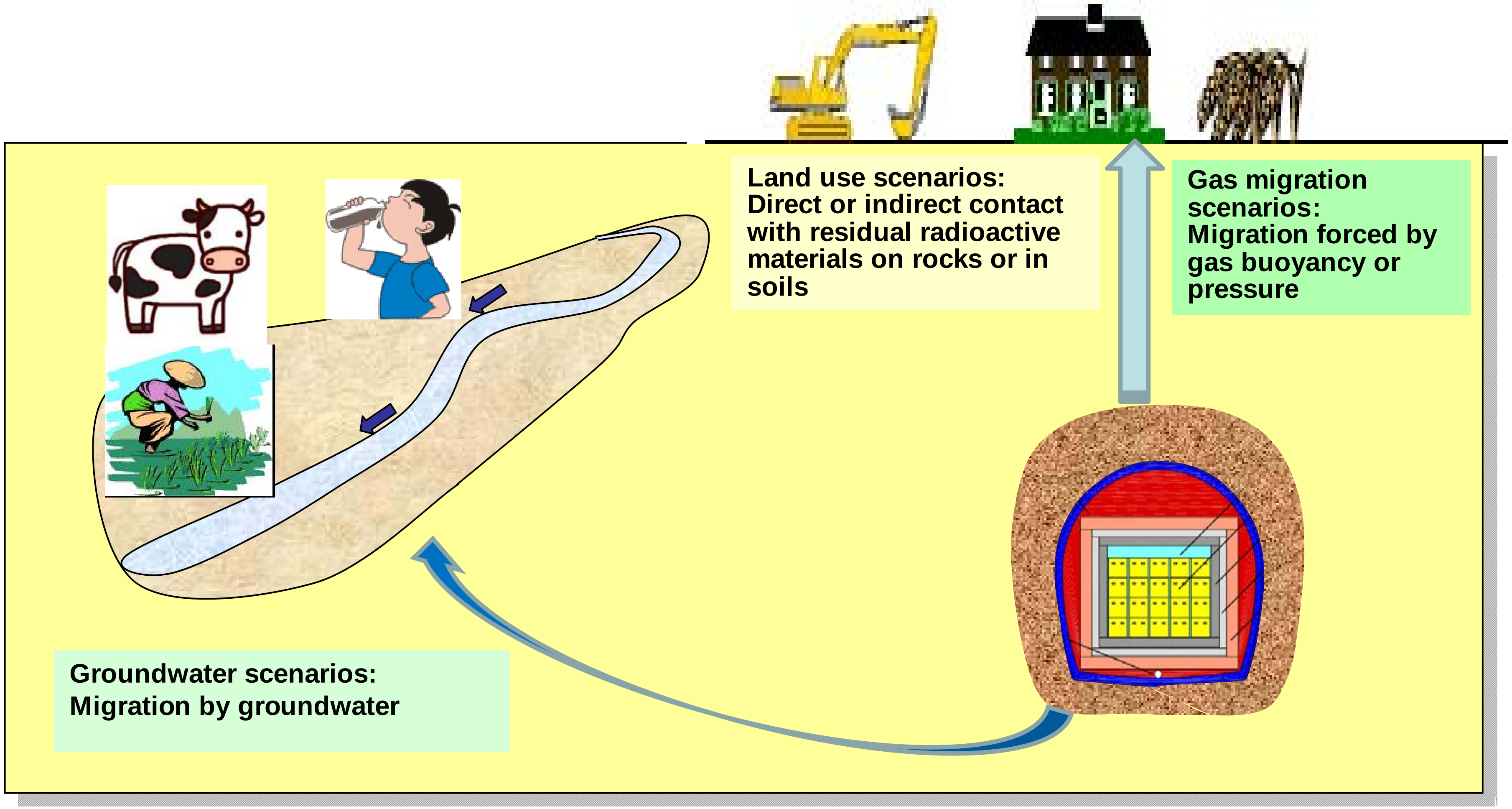
Time Period	Protective functions / characteristics of engineered barriers and the environmental conditions	Post-closure phases: Transient period	Post-closure phases: Period during which safety depends much on multiple barrier functions	Post-closure phases: Period during which natural barrier functions are expected to play a major role	Post-closure phases: Period during which the repository is expected to come close to the ground surface
		Time up to the stable conditions or the settling of changes in the states of the repository and the peripheral geological environment	In this period, evolutions in the repository conditions are expected be slow, because of the long-term stability of the geological environment.	In this period, the impacts of internal and external factors, which are difficult to exclude or reduce their effects from the setup of repository conditions, become manifest.	In this period, the repository is expected to come close to the ground surface as a result of phenomena such as uplift, erosion and sea level change
Policies concerning the setup of conditions	**Protective functions of engineered barriers:** - Retardation of nuclide migration - Physical resistance against inadvertent human intrusion **Properties of engineered barriers:** - Low permeability - Low diffusivity - Sorption coefficient - Low leaching rate -Other properties (mechanical properties, etc.) **Setup of the environmental conditions:** - Temperature (heat) - Hydraulic conditions - Dynamic conditions - Chemical conditions	- Ensure that engineered barriers are expected to withstand damage and degradation sufficiently well even when subjected to nonuniform progress of transient. 	Extrapolation based on scientific and technological bases and findings 	 Define conditions based on the evaluation of physical properties specific to barrier materials and functions inherent to natural barriers, assuming a conservative approach to uncertainties.	 - Define conditions that accord with the setup of conditions for the near-surface geological environment.

The illustrations of various phases are taken from "Policies Concerning the Setup of Long-Term Conditions for Engineered barriers (draft)" (Document No. 15-2 for the Class-2 Waste Burial Disposal Subcommittee) from the Central Study Institute of Electric Power Industry.

Chapter 5 - Setup of Likely Scenarios

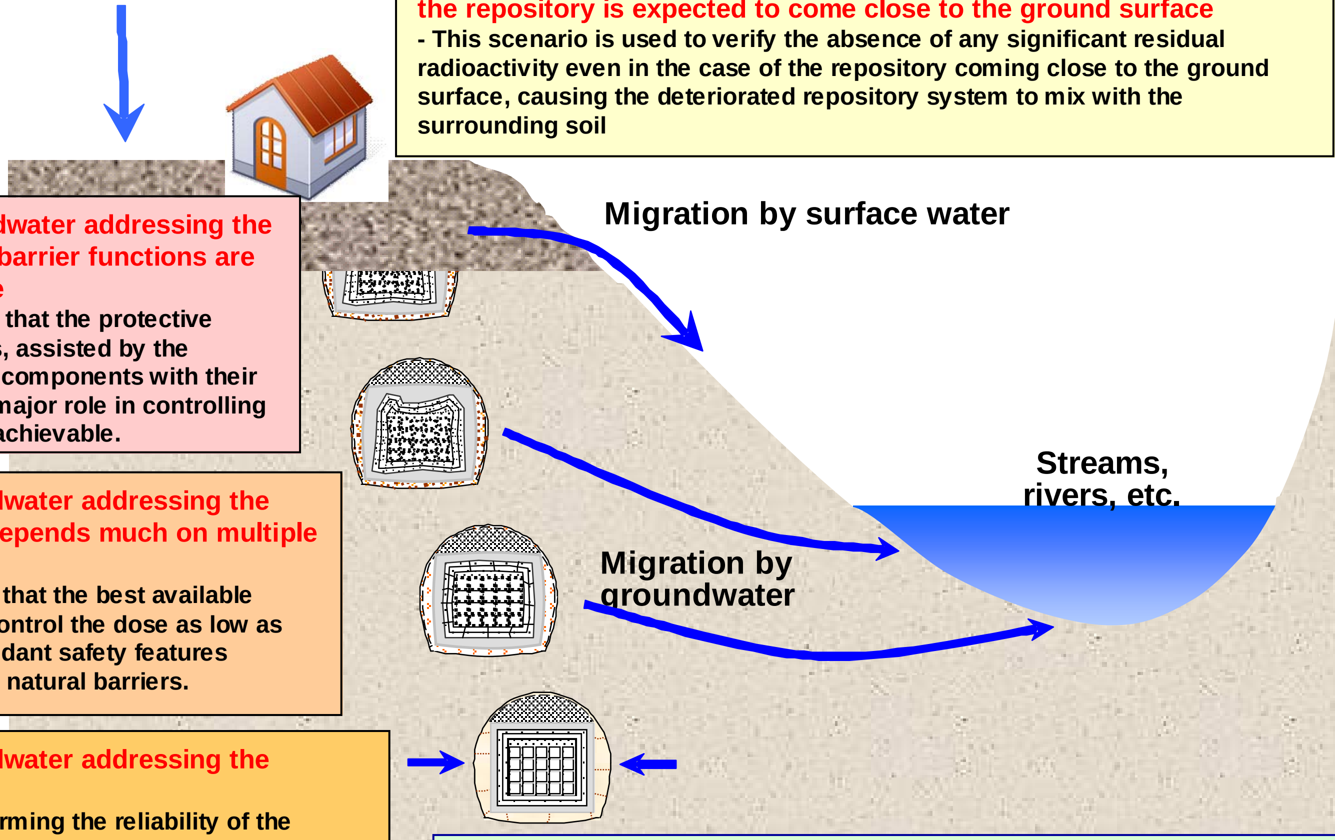
	Transient period	Period during which safety depends much on multiple barrier functions	Period during which natural barrier functions are expected to play a major role	Period during which the repository is expected to come close to the ground surface
Likely scenarios for groundwater	(Assessment of reliability of the multiple barriers arriving at intended conditions.)	**Likely scenario for groundwater** Assessment of the robustness of protection by the engineered and natural barriers	**Likely scenario for groundwater** Assessment of the robustness of protection, provided mainly by the natural barriers	**Likely scenario for groundwater** Assessment of impacts from weathering and erosion, assuming the state of mixing with the surrounding soil
Likely scenarios for gas migration	**Likely scenario for gas migration** -If the waste package is not capable of containment: This scenario is used for assessing impacts from the radioactive gas and from the generation and migration of radioactive radiolysis gas. -If the waste package is capable of containment: This scenario is not used.	**Likely scenario for radioactive gas migration** Assessment of impacts from the generation and migration of radioactive gas **Likely scenario for hydrogen gas migration** Assessment of impacts from the generation of hydrogen gas by radiolysis and from the generation and migration of hydrogen gas from the corrosion of metals	**Likely scenario for gas migration** Assessment of impacts from the gas generation under the conditions of physically damaged engineered barriers and chemical environmental changes	(Separate assessment of impacts from radon)
Likely scenarios for land use	**[Present land use]** **Likely scenarios for land use**(if there is any land that can be used after contamination along or around rivers and lakes in the downstream) **[Land use in the case topographical changes due to sea level change are considered]** **Likely scenarios for land use** Assessment of impacts from the use of dried lake beds in the downstream (impacts from construction and impacts from inhabitation) **[Land use in the case a terrain covered with sediments from uplift and erosion is considered]** **Likely scenarios for land use** Assessment of impacts from the use of a terrain covered with sediments from uplift and erosion (impacts from construction and impacts from inhabitation)			**[Land use in the case the repository is expected to come close to the ground surface]** **Likely scenarios for land use** Assessment of impacts from the use of contaminated land (impacts from construction and impacts from inhabitation).

Radioactive Material Migration Pathways to the Biosphere and Their Assessment by Different Scenarios



All pathways of radioactive nuclides to the biosphere must be addressed (considering migration by liquid, gaseous and solid media).

Evolution of the Likely Scenario for Groundwater through Different Time Periods



④ Likely scenario for groundwater addressing the period during which the repository is expected to come close to the ground surface

- This scenario is used to verify the absence of any significant residual radioactivity even in the case of the repository coming close to the ground surface, causing the deteriorated repository system to mix with the surrounding soil

③ Likely scenario for groundwater addressing the period during which natural barrier functions are expected to play a major role

- This scenario is used to verify that the protective functions of the natural barriers, assisted by the functions of engineered barrier components with their inherent properties, will play a major role in controlling the dose as low as reasonably achievable.

② Likely scenario for groundwater addressing the period during which safety depends much on multiple barrier functions

- This scenario is used to verify that the best available technologies are employed to control the dose as low as reasonably achievable by redundant safety features provided by the engineered and natural barriers.

① Likely scenario for groundwater addressing the transient period

- This scenario is used for confirming the reliability of the multiple barriers arriving at intended conditions.
- Groundwater in the outside tries to flow into the space of the engineered barriers.

Likely scenarios are used to perform assessments on highly probable and normally expected events with most probable parameters to verify that adequate measures are taken to control the dose as low as reasonably achievable in each time period.

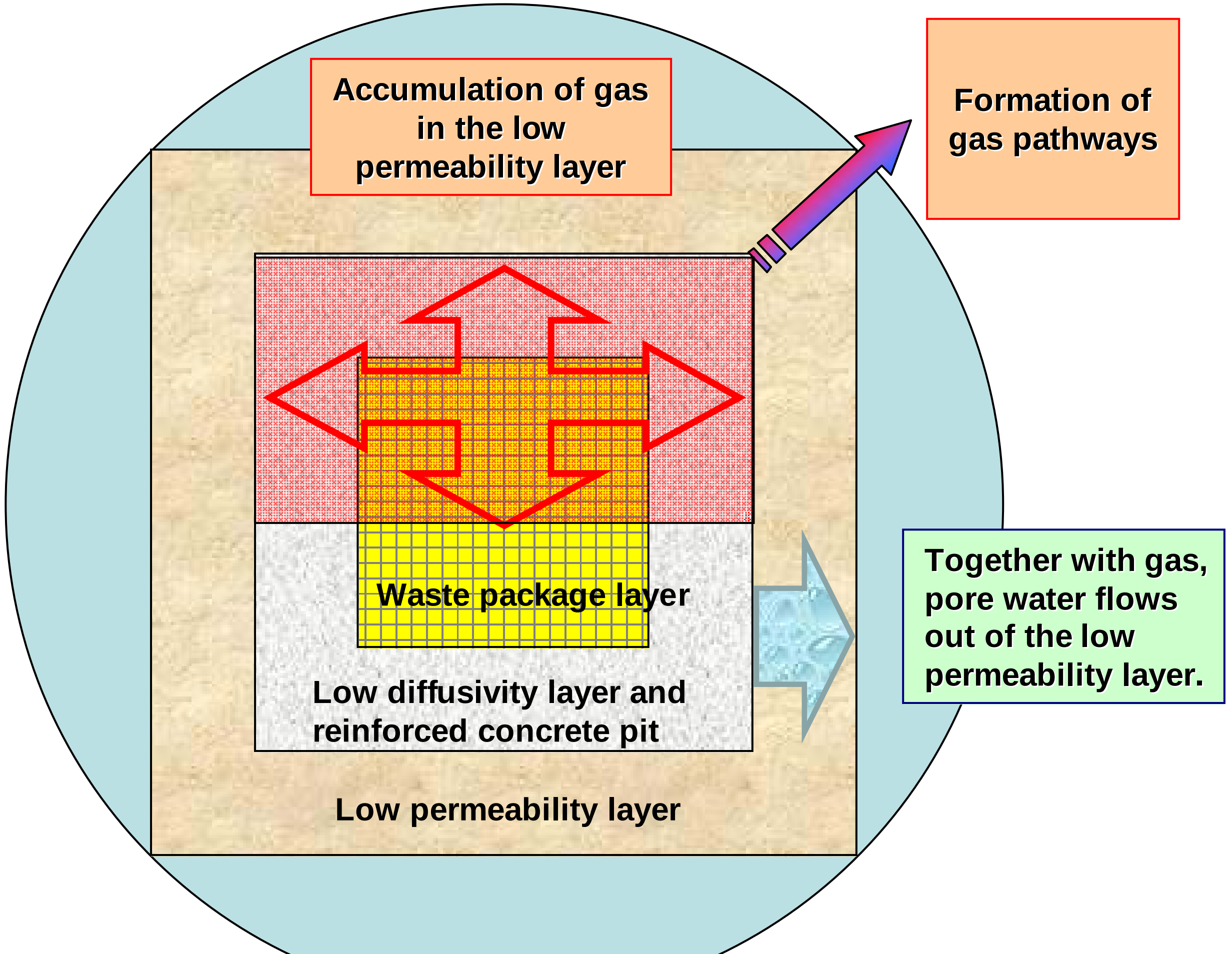
Evolution of the Likely Scenario for Gas Migration through Different Time Periods

① Transient period
Assessment of impacts from the radioactive gas and from the generation and migration of radioactive radiolysis gas

② Period during which safety depends much on multiple barrier functions
i. Assessment of impacts from the generation and migration of radioactive gas
ii. Assessment of impacts from the generation of hydrogen gas by radiolysis and from the generation and migration of hydrogen gas from the corrosion of metals

③ Period during which natural barrier functions are expected to play a major role
Assessment of impacts from the gas generation under the conditions of physically damaged engineered barriers and chemical environmental changes

④ Period during which the repository is expected to come close to the ground surface
(Independent assessment for radon-related impacts)



Waste packages for sub-surface disposal are not expected to contain any radioactive gas except for very small quantities of Tritium and methane gas, but do contain large quantities of metals. Therefore, the impacts of the hydrogen gas from the corrosion of these metals on the integrity of engineered barriers need to be assessed. In addition, in the case of the repository coming close to the ground surface, the impacts of radon, as a progeny

nuclide from uranium-series nuclides, need to be assessed.

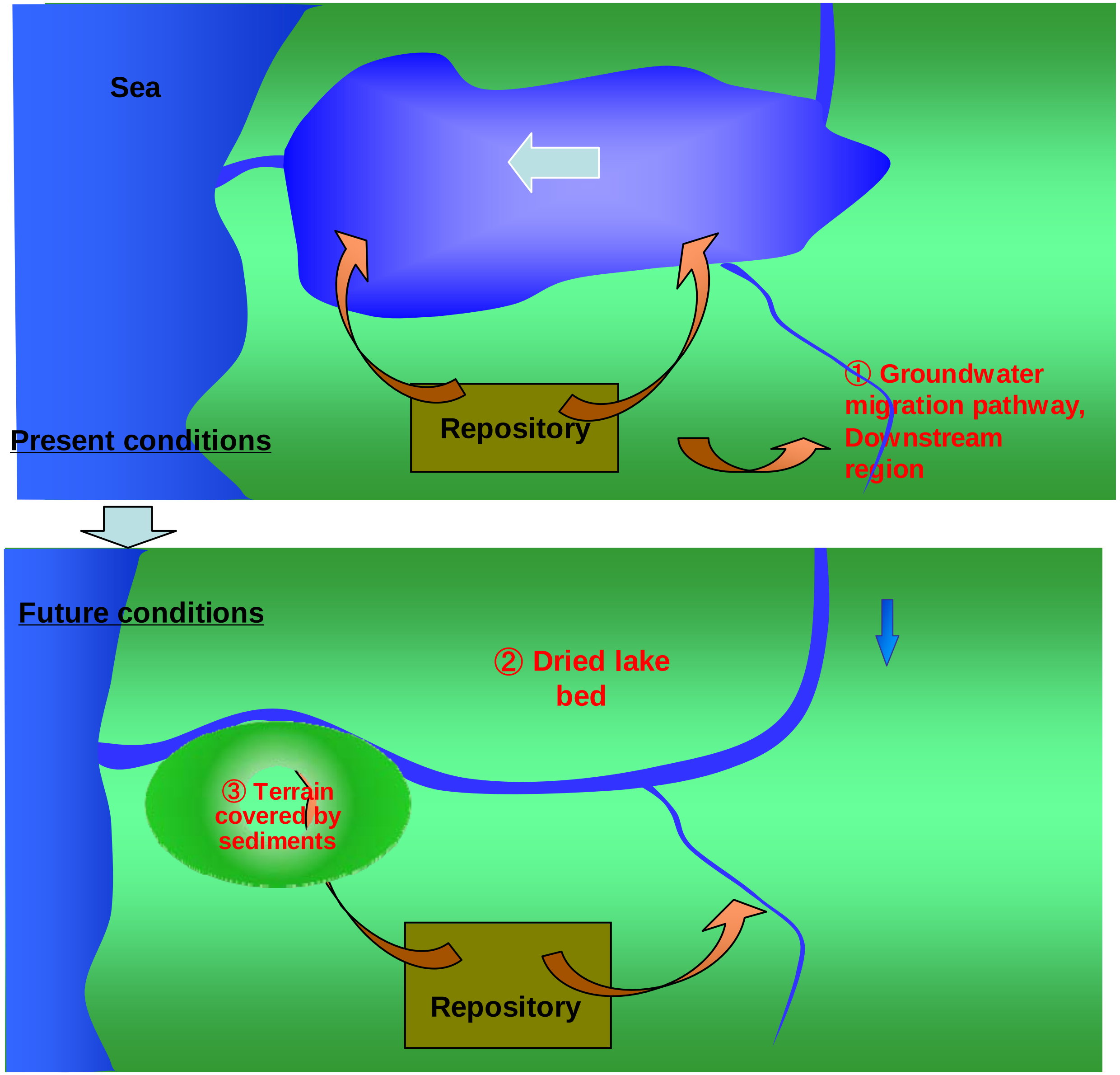
Evolution of the Likely Scenario for Land Use through Different Time Periods

① **Present land use:**
(if there is any land that can be used after contamination along or around rivers and lakes in the downstream)

② **Land use in the case topographical changes due to sea level change need to be considered:**
Assessment of impacts from the use of dried lake beds in the downstream (impacts from construction and impacts from inhabitation)

③ **Land use in the case a terrain covered with sediments from uplift and erosion:**
Assessment of impacts from the use of a terrain covered with sediments from uplift and erosion (impacts from construction and impacts from inhabitation)

④ **Land use in the case the repository is expected to come close to the ground surface:**
Assessment of impacts from the use of contaminated land (impacts from construction and impacts from inhabitation)



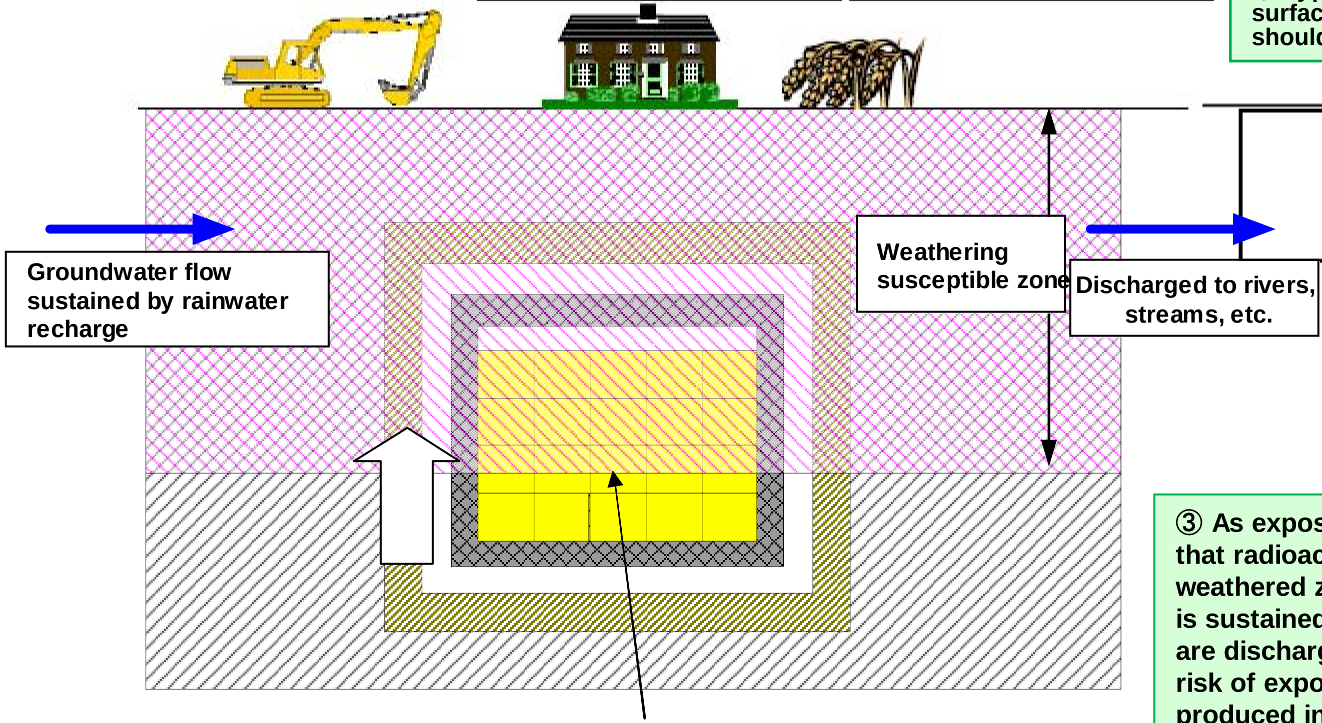
Assessment of Impacts from the Repository Coming Close to the Ground Surface as a Result of Phenomena Such as Uplift, Erosion and Sea Level Change

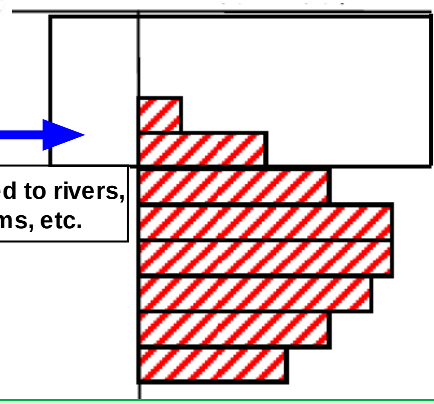
Construction
-Direct radiation impacts from the excavated spoil
-Inhalation of dust particles from the excavated spoil

Inhabitation
-Direct radiation impacts from the excavated spoil
-Inhalation of dust particles from the excavated spoil

Ingestion of crops
-Impacts from the ingestion of agricultural products (by inhabitants)

④ Typical uses of land use on the ground surface above or around the closed repository should be considered.





Excavation by construction activities

The distribution of radioactivity concentration in the weathered zone should be considered

① The repository may come closer to the ground surface and to the weathering susceptible zone as a result of phenomena such as uplift, erosion and sea level change.

② It is assumed that, in the weathering susceptible zone, the deteriorated repository system is mixed with the surrounding soil. According to the velocity of uplift, radioactive nuclides are released from the repository system to the weathering susceptible zone.

③ As exposure pathways, it should be assumed that radioactive nuclides are carried from the weathered zone by the flow of groundwater, which is sustained by the rainwater recharge, until they are discharged to rivers and streams, producing the risk of exposure by the ingestion of food-stuffs produced in the downstream watershed or by the use of river or stream water.

The Likely scenario should address land use on the ground surface above or around the closed repository other than groundwater scenario to ensure the verification of the absence of any significant risk from residual radioactivity scenario.

Chapter 6 - Setup of Less-likely Scenarios

	Transient period	Period during which safety depends much on multiple barrier functions	Period during which natural barrier functions are expected to play a major role	Period during which the repository is expected to come close to the ground surface
Less-likely scenarios for groundwater	(Assessment of factors that cause variations to the initial construction conditions)	**-Typical less-likely scenarios for groundwater** **-Scenario for the partial loss of barrier functions** Robustness assessment that assumes the partial loss of barrier functions with the aim of assessing the robustness of multiple barriers and the aim of assessing the importance of individual protective functions	**-Typical less-likely scenarios for groundwater** **-Scenario for the partial loss of barrier functions**	**-Typical less-likely scenarios for groundwater** **-Alternative less-likely scenario for groundwater** Use of an alternative model for representing the weathered zone **- Scenario for the safety assessment margins against uncertainties**
Less-likely scenarios for gas migration	**- Typical less-likely scenarios for gas migration**	**-Less-likely scenario for radioactive gas migration** **-Less-likely scenario for hydrogen gas migration**	**- Typical less-likely scenarios for gas migration**	(Separate assessment of impacts from radon)
Less-likely scenarios for land use	**[Present land use]** -Typical less-likely scenarios for land use **[Land use in the case topographical changes due to sea level change are considered]** -Typical less-likely scenarios for land use -Scenario for the partial loss of barrier functions **[Land use in the case a terrain covered with sediments from uplift and erosion is considered]** -Typical less-likely scenarios for land use -Scenario for the partial loss of barrier functions			**[Land use** In **the case the repository is expected to come close to the ground surface]** -Typical less-likely scenarios for land use -Alternative less-likely scenario for groundwater Use of an alternative model for representing the weathered zone - Scenario for the safety assessment margins against uncertainties

In order to ensure that the repository system design adequately accounts for various uncertainties, less-likely scenarios are prepared to address various factors contributing to variations, which are relatively unlikely but still important in the context of safety assessment conducted with the likely scenarios. Less-likely scenarios are used to verify that it can reasonably be judged that the impacts from such variations will remain limited and the repository system is robust enough to withstand them.

General uncertainties in safety assessment, including uncertainties concerning properties of the geological environment, are addressed by these less-likely scenarios.

Guides for the Safety Assessment for less-likely Scenarios

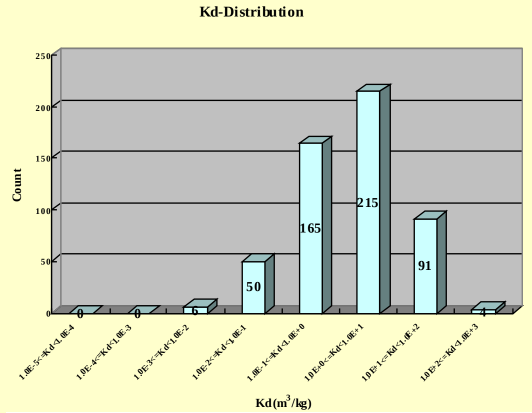
Analysis of factors that cause variations from the likely scenarios
- Preparation of plural less-likely scenarios for each likely scenario

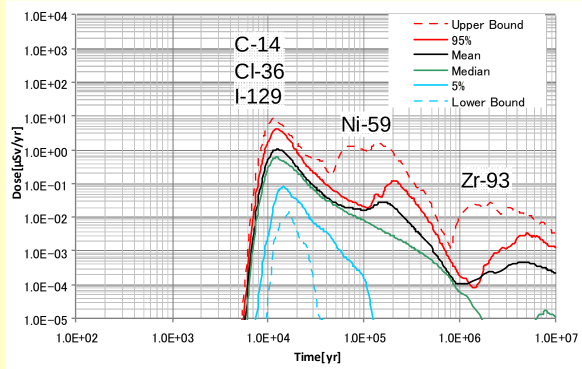
Completeness in the identification of variation factors
- The setup of conditions is preceded by the identification of variation factors by FEP analyses, etc.

Probability and scientific reasonability of variation factors
- If sufficient quantities of statistical data are available, use them to select values in the 97.5% one-sided confidence interval.
- If sufficient quantities of statistical data are not available for addressing uncertainties in long-term safety assessment, make the best use of available scientific and technological findings to set up conditions with sufficient allowances based on a conservative approach.
- If severale parameters largely affect the assessment results, it is useful to evaluate the uncertainties with such parameters by a probabilistic method to verify reasonability in the setup of conditions

Assessment of the repository system robustness
- A partial loss of safety functions is assumed to verify that the repository system does not depend excessively on any single safety feature.
- However, it is not necessary to assume the absence of contributions from the components that have sufficiently demonstrated their reliability or from inherent properties of materials, etc., provides that such contributions are expected to persist through environmental changes, etc. Rather, scenarios should be designed to address uncertainties in long-term safety assessment.

Example of statistical data on the distribution coefficient





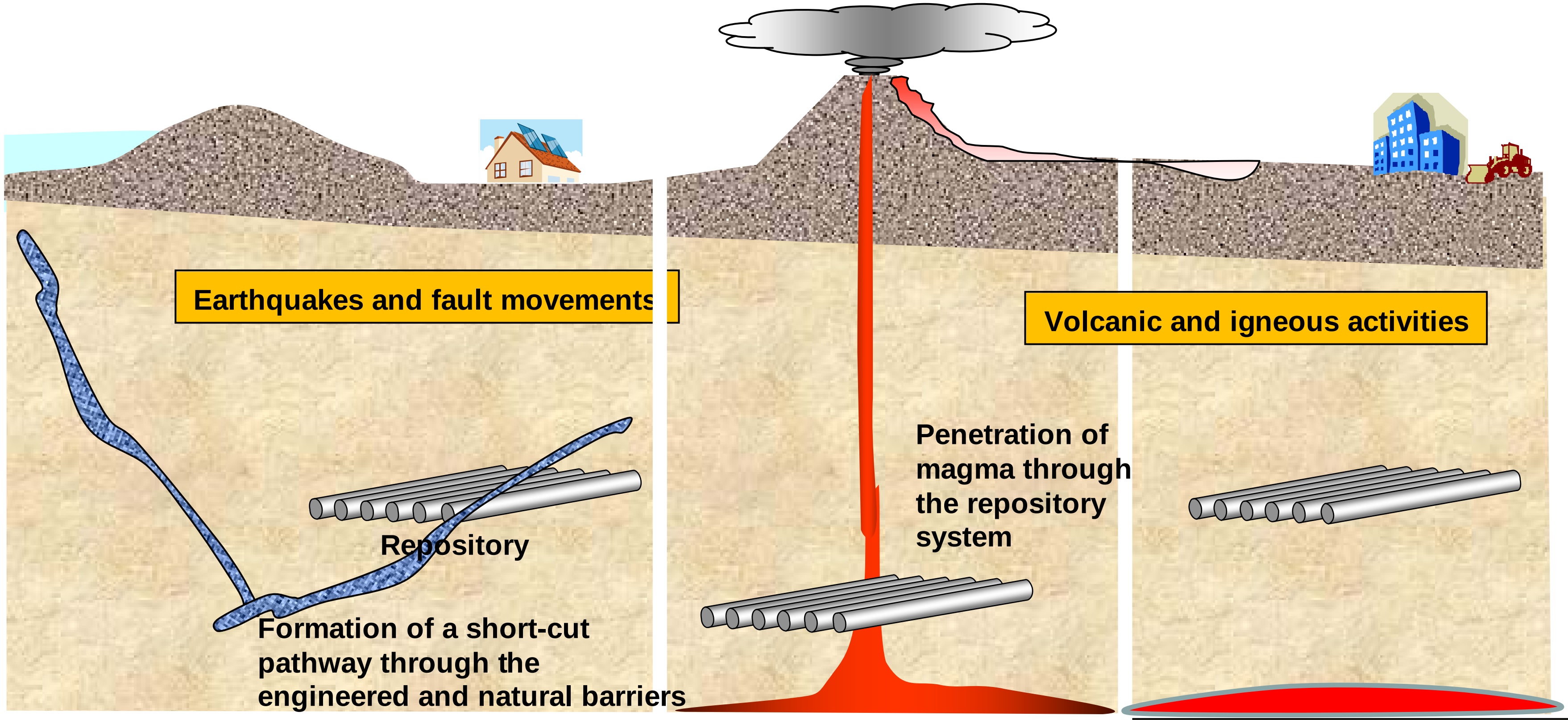
Aoki et al., "Study on uncertainty of safety assessment parameters for intermediate depth disposal (Ⅲ) Example dose calculation" Autumn, 2009, AESJ

Examples of Scenarios to Be Addressed by less-likely Scenarios for Groundwater Prepared for the Period during Which Safety Depends Much on Multiple Barrier Functions

	Waste package	Engineered barriers			Natural barriers		Biosphere
	Leaching rate	Low permeability	Low diffusivity	Retardation	Physical isolation	Chemical retardation	Quantity of diluting water, etc
Likely scenarios for groundwater	○	○	○	○	○	○	○
Typical less-likely scenarios for groundwater	△	△	△	△	△	△	△
Scenario for the partial loss of barrier functions of engineered barriers	▼	○	○	○	○	○	○
	○	▼	○	○	○	○	○
	○	○	▼	○	○	○	○
	○	○	○	▼	○	○	○
Scenario for the partial loss of natural barrier functions of natural barriers	○	○	○	○	▼	○	○
	○	○	○	○	○	▼	○

○: Addressed by likely scenarios for groundwater.
△: Addressed by typical less-likely scenarios considering variation factors that are relatively improbable but are important in the context of safety assessment.
▼: Addressed in conservative assessment procedures that assume a partial loss of functions for the verification of robustness. (Such assessments are performed for radioactive materials with important safety implications and for the functions required for the protection of such materials based upon FEP analyses for actual site.)

Chapter 7 – Setup of Rare Natural Event Scenarios



Assessment of mechanical failure by earthquakes and fault movements

Assessment of mechanical failure by volcanic and igneous activities

Assessment of extreme degradation by thermal or chemical effects by volcanic and igneous activities

Even after including the scenarios that address relatively improbable events, there remain some uncertainties. Rare natural event scenarios are used for verifying that no additional special measure for radiation protection is deemed to be required even after giving attention to such remaining uncertainties.

Chapter 8 - Setup of Inadvertent Human Intrusion Scenarios

Scenario name	Boring scenarios			Tunnel excavation scenarios		Extensively exploited land use scenarios
	Scenario for the direct boring and core observation	Scenario for the formation of a short-cut of migration pathway	Scenario for the pumping of groundwater from a bore hole near the repository	Scenario for the excavation of a tunnel near the repository	Scenario for the excavation of a tunnel through the repository	
Assessment objective	- Verify the adequacy of radioactivity concentration of each waste package.	- Verify the adequacy of radioactivity inventory in each cavern.	- Verify the adequacy of radioactivity inventory in each cavern and the adequacy of the engineered barrier capability for retarding the migration of radioactive materials.	-Verify the adequacy of the engineered barrier capability for retarding the migration of radioactive materials and of the duration in which this capability is maintained.	- Verify the adequacy of the engineered barrier capability for physical resistance and of the duration in which this capability is maintained.	- Verify that, even in the case of the repository coming close to the ground surface, the impacts from the inventory (and the radioactivity concentration) of radioactive materials with a long half life will not result in a dose that exceeds the dose guides suggested by the guideline.

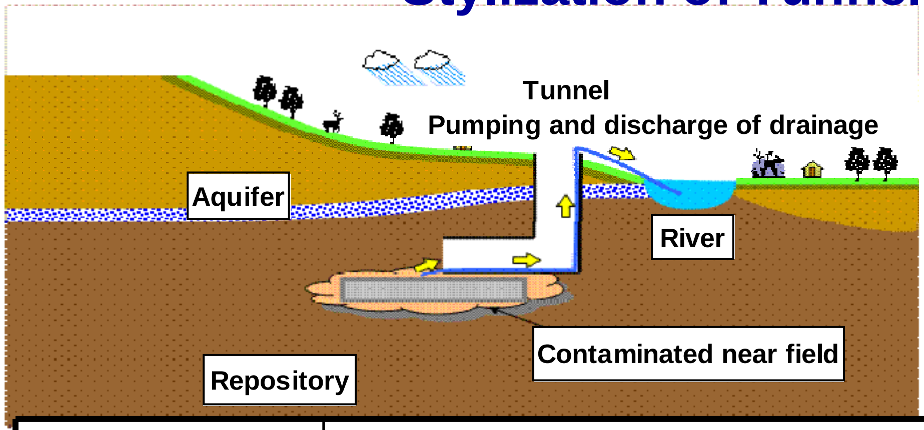
Scenarios for inadvertent human intrusion :

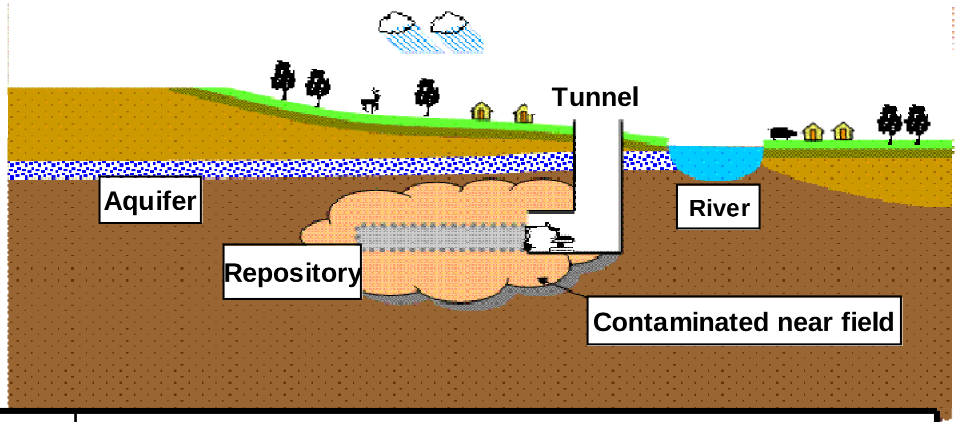
-These scenarios are used to verify that adequate measures are taken to reduce the possibility of human intrusion and to control the exposure dose as low as reasonably achievable. They are also used to verify that no additional special measure for radiation protection is deemed to be required even after choosing a conservative assessment approach.

-In order to confirm the safety of residents around the site, events connected with stylized human actions are analyzed using the most probable assumptions for following related natural processes, and therefore, these scenarios serve the purpose of verifying the probability of such impacts being successfully reduced. A conservative assessment approach, which properly accounts for uncertainties, is required for verifying the adequacy of sub-surface disposal and that no additional special measure for radiation protection is deemed to be required .

-The dose for individual intruder(s) should be estimated according to a stylized scenario, for both cases of the most probable assumptions and the conservative ones in order to estimate the maximum dose and to verify that no additional special measure for radiation protection is deemed to be required .

Stylization of Tunnel Excavation Scenarios





Scenario name	Scenario for the excavation of a tunnel near the repository	Scenario for the excavation of a tunnel through the repository
Stylization of inadvertent human intrusion	- Objective cavern: Based on a conservative approach, assume that a tunnel is excavated across the most conservative point along a line that runs perpendicularly to the group of caverns for disposal. -Concentration of radioactive materials in the drainage from the funnel: Assume that all radioactive materials released from caverns near the tunnel flow into the tunnel.	- Objective cavern: Assume the excavation of a tunnel through a single cavern for disposal. However, if two or more cavities exist on a straight line at the same depth with little distance from each other, for example, consider the total length of all these cavities. - Timing of excavation: Assume that the tunnel is excavated at a time when it has become impossible to recognize the presence of engineered barriers. - Excavation technique: Based on the current technology, assume a general and reasonable excavation technique that is likely to be used in consideration of the geological features (particularly of rocks) of the chosen site. - Geometry of excavated spoil storage place etc.: Make assumptions in consideration of the common geometry of spoil storage place presently chosen for the safety measures.
Conditions to be assumed in the assessment of the adequacy of mitigation measures	The assessment may require the setup of probable assumptions concerning the hydraulic gradient for the case that assumes the excavation of a tunnel above the repository and the inherent properties of engineered barriers.	Probable assumptions may be accepted to support the reliable prediction of the time at which the engineered barriers will become unrecognizable based on a reliable assessment concerning the gradual loss of physical resistant capability due to corrosion, etc.
Conditions to be assumed in the assessment of the adequacy of sub-surface disposal	The assessment may require the setup of conservative assumptions concerning the hydraulic gradient and the inherent properties of engineered barriers leading that larger quantities of radioactive materials may migrate.	The assessment may require the setup of conservative assumptions concerning the acceleration of corrosion, etc., due to environmental changes, leading that the engineered barriers may become unrecognizable at an earlier timing.
Exposure pathways and the residents around the site	Assume that the drainage from the tunnel is discharged directly to rivers, etc. Address the exposure of residents who use water from these rivers, etc.	Address the exposure of residents who use water from rivers, etc., into which the rainwater may flow after permeation into the excavated spoil.
Exposure pathways and individual intruders	none	Address the internal and external exposure of tunnel excavation workers.

Chapter 9 - Termination of the Institutional Control Period

Likely scenarios	By means of the safety assessment of likely scenarios, the applicant shall present the scientific grounds about the basic design and its policy for assuring that, at a sufficient probability, the risk will be limited to 10^{-6}/year or less with the radiological impact of 10 μ Sv/year or less.
Less-likely scenarios	By means of the safety assessment of less-likely scenarios that are designed to address uncertainties in the conditions assumed by the likely scenarios, the applicant shall demonstrate that the radiological impact from such uncertainties will be limited to 300 μ SV/year or less.
Rare natural event scenarios	By means of the safety assessment of rare natural event scenarios that are designed to address rare natural event for further assurance, the applicant shall demonstrate that the radiological impact from rare natural events will not exceed 10mSv/year fundamentally and never exceed 100mSv/year, or, in other words, the applicant shall demonstrate that a further special measure for radiation protection will not always be required even after the occurrence of rare natural events.
Inadvertent human intrusion scenarios	By means of the safety assessment of inadvertent human intrusion scenarios, which should involve the setup of such scenarios according to stylized procedures, etc., the applicant shall demonstrate that the radiological impact from inadvertent human intrusion will not exceed the criterion of 1-10mSv/year for residents around the site, and that the radiological impact on individual intruders will not exceed 10mSv/year fundamentally and never exceed 100mSv/year.
Transition into the post -institutional control phase	Based on the comprehensive review of the results of different types of safety assessment described above, it may be judged that the possibility of the proposed disposal business achieving a transition into the post-institutional control phase is sufficiently supported by scientific grounds.

Procedure of Regulation Support Research and Development on Sub-Surface Disposal

Analytical study and other work projects previously conducted or participated by JNES in support of the Nuclear Safety Commission

FEPC "Quantities and Radioactivity Concentration Levels of Power Station Waste That Exceeds the Upper Bounds of Radioactive Concentration for Near Surface Disposal Specified in the Ordinance" (BD 2-2-1; October 21, 2005)

JNES and RWMC "Examples for the Classification of Safety Assessment Scenarios Based on the Risk-Informed Approach" (BD 5-Reference 1 ; June 22, 2006)

→ JNES "Examples of Analysis Conducted with Typical Safety Assessment Scenarios for Low Level Radioactive Waste Disposal Facilities" (BD 6-1; September 19, 2006)

↓

Assignment from Subcommittee to Update BD 6-1 in reference to "Upper Bounds of Radioactive Concentration for Burial of Low Level Radioactive Solid Waste" (NSC; May 2007), etc.

→ JNES "Update of Examples of Analysis Conducted with Typical Safety Assessment Scenarios for Low Level Radioactive Waste Disposal Facilities" (C2 7-1; May 2, 2008) in reference to JNES C2 3-2-2 with the inclusion of additional analyses based on comments from committee members

↓

FEPC "Quantities and Radioactivity Concentration Levels of Waste for Sub-Surface Disposal (C2 11-1; Sep. 24, 2008)

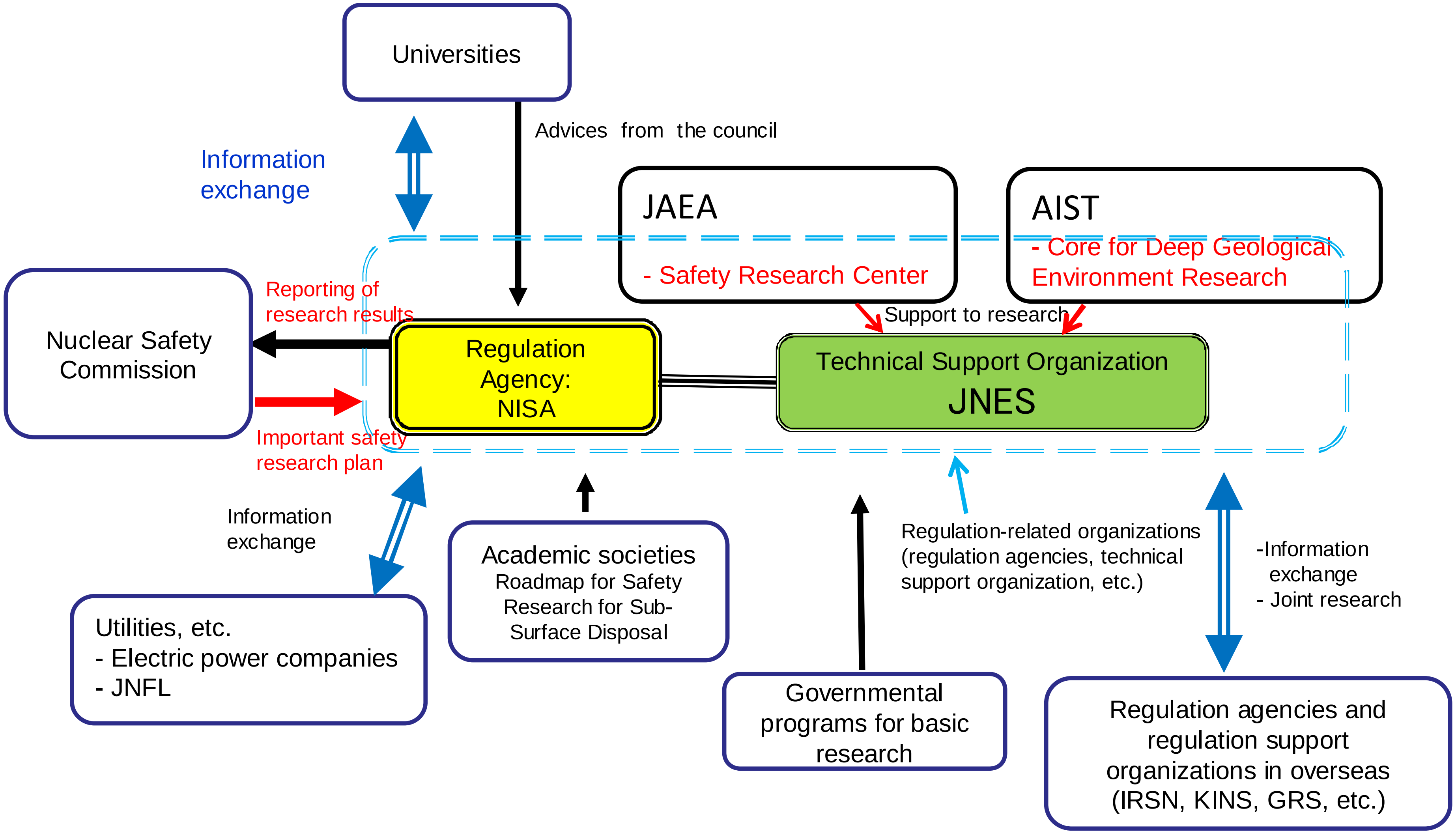
→ JNES "Reanalysis for the Examples of Analysis Conducted with Typical Safety Assessment Scenarios" (C2 11-2; Sep. 24, 2008)

BD: Burial Disposal Subcommittee of NSC; C2: Class-2 Waste Disposal Subcommittee of NSC

key Safety Studies for Sub-Surface Disposal and Near Surface Disposal

	Fiscal year	～H21	H22	H23	H24	H25	H26～
Near surface disposal	Legal procedures for near surface disposal	Confirmation procedures concerning waste package Business licensing application and safety examination	(Disposal with engineered barrier: JNFL (during operation) Disposal without engineered barrier (waste from reactor facilities, etc.)	Examination of the burial disposal facility	Confirmation of waste package		Specific procedures for the disposal of waste from research institutions, etc., and uranium bearing waste, etc., are to be discussed in reference to the disposal plans to be prepared in the future by the utilities, etc.
	Studies on near surface disposal -Establishment of analytical methodology for safety examination	Establishment of analytical Methodology for safety examination					
	-Establishment of procedures for the confirmation of safety near surface disposal with or without engineered barrier	(Disposal with engineered barrier) Confirmation procedures have been established for the disposal of homogenous/uniform solidified waste package and filled-in solidified waste package Preparation of facility examination procedures Preparation of waste package confirmation procedures (JNES) Specific procedures are to be discussed in reference to the disposal plans to be prepared in the future by the utilities, etc., and the specifications of new waste package					
Sub-Surface disposal	Legal procedures for sub-surface disposal	NSC Preparation of safety review guidelines Preparation of judgment criteria for the safety review (as required) Business licensing application and safety review		Examination of the burial disposal facility	Confirmation of waste package	Periodical safety reviews	
	Studies on sub-surface Disposal - Listing of topics to be addressed by the safety examination and the establishment of analytical procedures	Listing of issues to be addressed by the safety examination Establishment of analytical methodology for safety review					
	-Establishment of procedures for the confirmation of safety	Preparation of facility examination procedures Preparation of monitoring procedures	Preparation of waste package Confirmation procedures (JNES)		Specific procedures are to be discussed in reference To the disposal plans to be prepared in the future by the utilities, etc.		

Organizational Framework for Future R&D That Support the Regulation of Sub-Surface Disposal



Selection of Items To Be Addressed by Regulation Support R&D in the Future

Needs of NISA

"R&D items to be addressed for meeting the needs"
Overall listing of important items that are expected to require NISA's technological judgments in the future

Establishment of evaluation methodology for safety features and behaviors of engineered barriers by engineering-scale model

① "R&D items that remain unaddressed by other institutions" (*)
Among the items identified as "R&D items to be addressed for meeting the needs," those which have not been addressed by other institutions are selected.

Research and development for the safety of sub-surface disposal of reactor internals, etc." Sub-Surface Disposal WG of the Special Committee of JAES (FY2006)

③ "R&D items that are already addressed by other institutions"
Among the items identified as "R&D items to be addressed for meeting the needs," those which are already addressed by other institutions are listed.

Note (*): The term "other institutions" refers to "institutions other than those which are engaged in regulation support researches."

Preparation of data that support safety review
Preparation of analytical methodology for cross-checking
Preparation of later-stage regulatory procedures such as confirmation of waste package and facility examination

② "Topics that should be addressed by NISA from an own standpoint"
Among the items identified as "R&D items that have been addressed by other institutions," those which should be addressed by NISA from an own standpoint (e.g. procedures for verifying the acceptability of assessment results produced by the utilities) are listed.

Whatever resources that may contribute to the fulfillment of the NISA's needs should be actively be used or shared after ensuring their qualities to support Safety Regulation.

R&D Items to be addressed by regulation support organization in the future

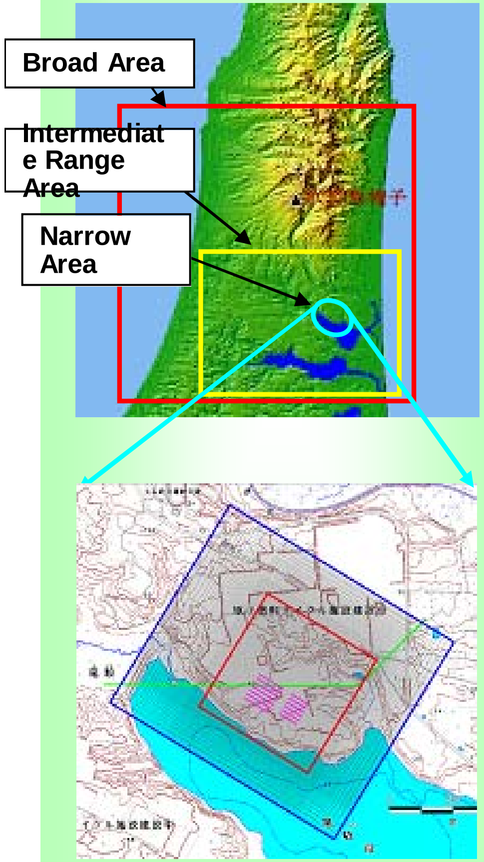
Accumulation of domestic and international research results

Ⅴ. Major Current Regulatory Safety R&D on Sub-Surface Disposal and Key Technical Issues

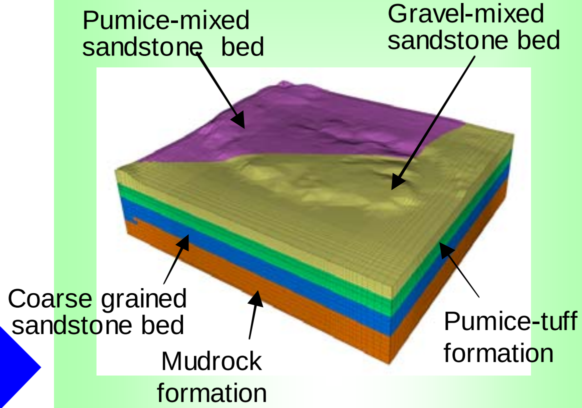
1. Safety R&D on Groundwater Flow Assessment
2. Safety R&D on Nuclide Migration Assessment
3. Safety R&D on Protection Capability Assessment of Engineered Barriers

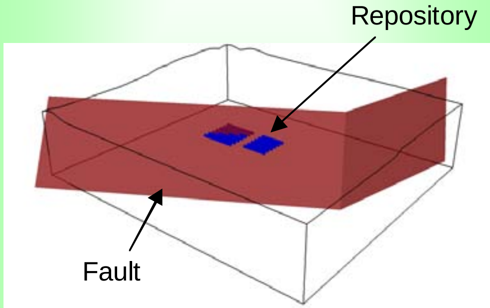
Assessment using General Purpose Multidimensional Flow Analysis Code

Setup of the objective area, faults and repository location

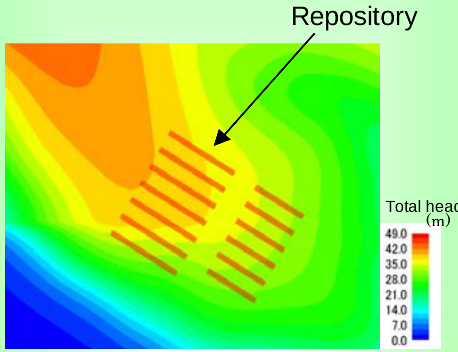


Setup of the hydro-geological models for the objective area, boundary conditions, etc.

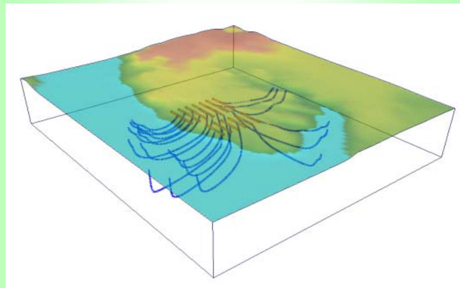




Groundwater flow analysis and the analysis of groundwater travel distance and time



Example of groundwater flow analysis results (profile at the elevation of -89m)

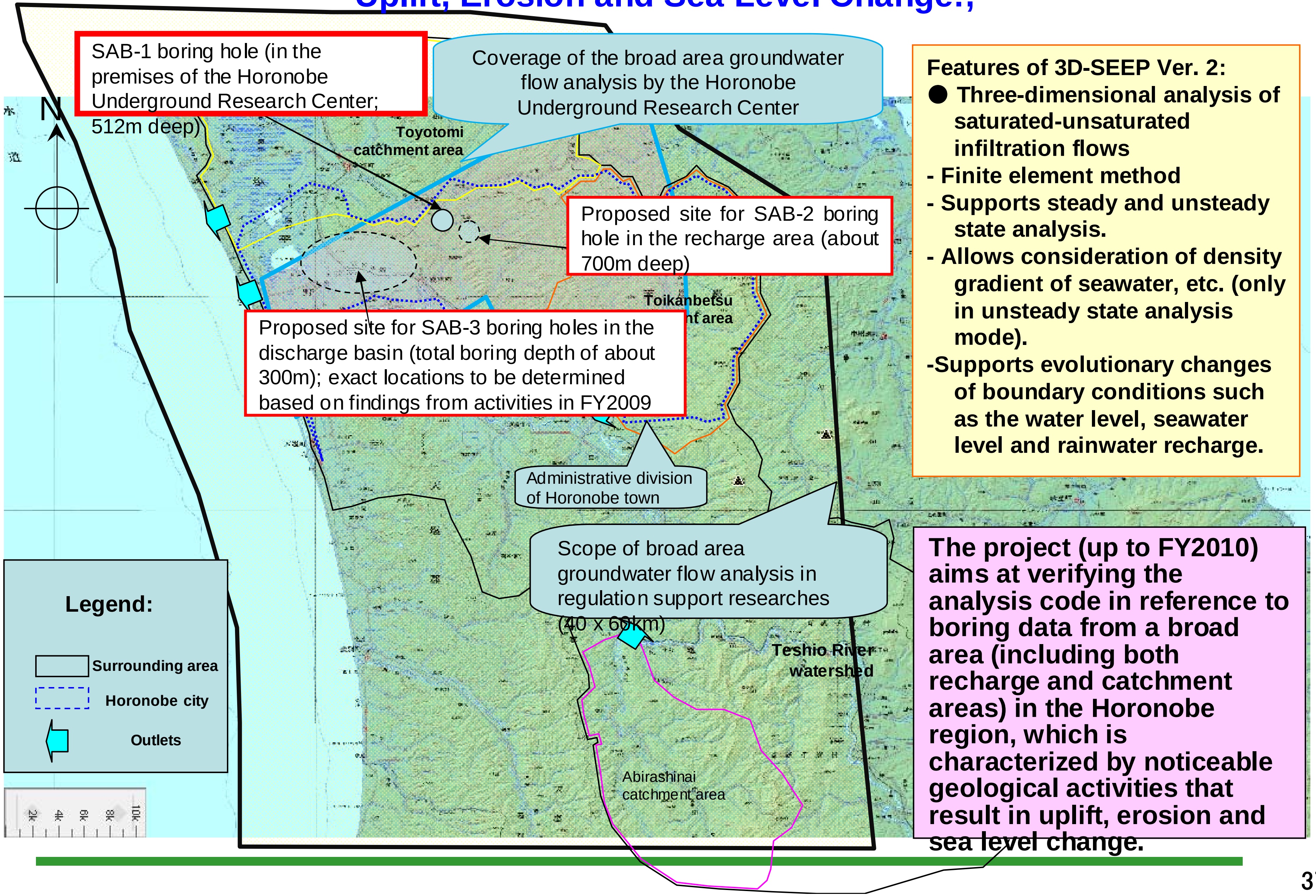


Example of groundwater migration pathway analysis results (determination of travel distance and time)

Safety R&D on Groundwater Flow Assessment

Assessment Objective	Analysis Code	Current Safety R&D
Broad area multi-dimensional groundwater flow assessment	General purpose multidimensional flow analysis codes: TOUGH2, Dtransu, MODFLOW	-JNES has been working toward the establishment of procedures for cross-check analysis. -JNES is preparing the Analysis Support System and Quality Assurance Support System to improve the reliability of cross-check analysis.
Near field multidimensional groundwater flow assessment	Same as the above	
Groundwater flow assessment coupled with uplift, erosion and sea level change	Groundwater flow analysis code that accounts for upheaval, erosion and sea level change: 3D-SEEP	-JAEA Safety Research Center is consigned by NISA to develop the code mainly for the safety assessment of geological disposal. - At present, an experiment for verification of the code is jointly conducted by JAEA, AIST and INES at the JAEA's Horonobe Underground Research Center.

Verification of Groundwater Flow Analysis Code (3D-SEEP) That Accounts for Uplift, Erosion and Sea Level Change:,



Features of 3D-SEEP Ver. 2:

- ● Three-dimensional analysis of saturated-unsaturated infiltration flows
- Finite element method
- Supports steady and unsteady state analysis.
- Allows consideration of density gradient of seawater, etc. (only in unsteady state analysis mode).
- Supports evolutionary changes of boundary conditions such as the water level, seawater level and rainwater recharge.

The project (up to FY2010) aims at verifying the analysis code in reference to boring data from a broad area (including both recharge and catchment areas) in the Horonobe region, which is characterized by noticeable geological activities that result in uplift, erosion and sea level change.

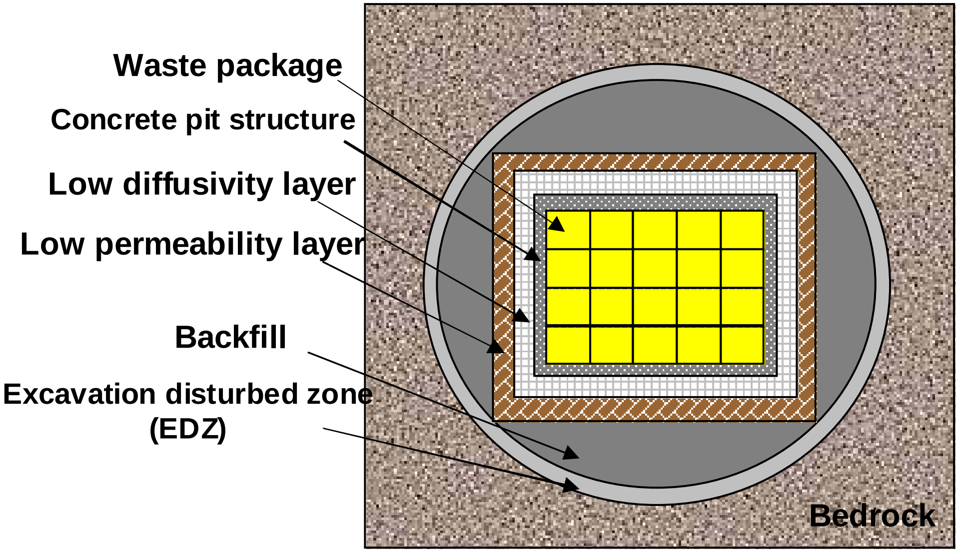
Safety R&D on Nuclide Migration Assessment

Nuclide Migration Assessment Methods	Assessment Objective	Current Safety R&D
Formula concerning the four important factors in groundwater scenarios	- Simplified expression derived from the equation of nuclide diffusion by advection-Contributes to qualitative and quasi-quantitative understanding of major factors that impact the assessment of exposure dose	- Suzuki et al., "A study on safety assessment methodology of radioactive waste disposal facility with multiple engineered barrier system" , Nuclear Power Backend Study, Vol.15, No. 2, pp. 87-98
One-dimensional nuclide migration modeling for groundwater scenarios with the consideration of the degradation of engineered barriers	- Safety assessment models that account for various uncertainties about parameters and the impacts of the degradation on parameters that have major impacts on safety assessment	JNES "Reanalysis for the Examples of Analysis Conducted with Typical Safety Assessment Scenarios" (C2 11-2)
One-dimensional nuclide migration modeling with the consideration of changes in travelling pathways through natural barriers	- Assessment models that account for evolutionary changes in travelling pathways and time due to uplift, erosion and sea level change	- JNES "Reanalysis for the Examples of Analysis Conducted with Typical Safety Assessment Scenarios" (C2 11-2)
Multidimensional nuclide migration modeling	- Detailed analysis for conservatively representing nuclide behaviors in a multidimensional system by one-dimensional models	JNES "Report on Investigations in FY2007 Concerning Radioactive Waste Disposal (Investigations Concerning Sub-Surface Disposal)"; September 2008 -Suzuki et al., "THE DEVELOPMENT OF HIGH PERFORMANCE NUMELICAL SIMULATION CODE FOR TRANSIENT GROUNDWATER FLOW AND REACTIVE SOLUTE TRANSPORT PROBLEMS BASED ON LOCAL DISCONTINUOUS GALERKIN MEHTOD"; Collection of Papers by the Japan Society of Civil Engineers, Vol. 65 No. 3, pp. 703-715, August 2009

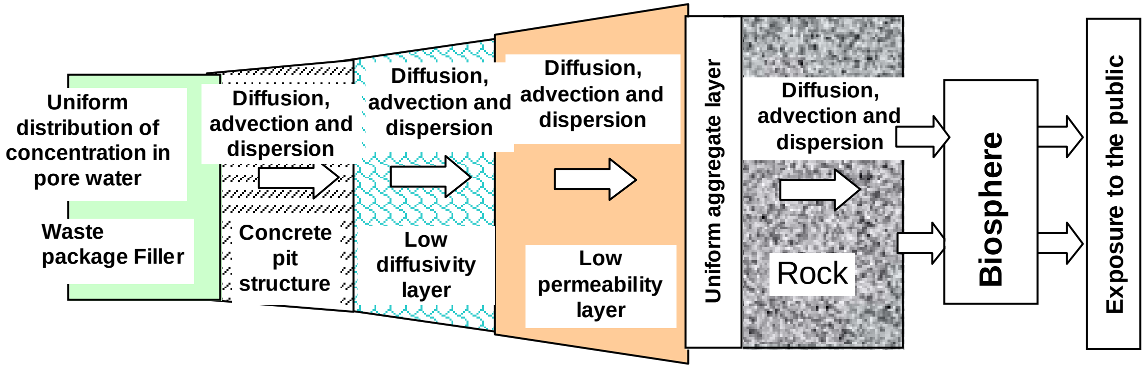
Formula Concerning the Four Important Factors In Groundwater Scenarios: *Di* = *Qi* x *Ei* x *Gi* x *Bi*

Di Exposure dose (Sv/y)	*Qi* Radioactivity inventory (Bq)	*Ei* Performance indicator for the nuclide migration control capability provided by engineered barriers (1/y)	*Gi* Performance indicator for the isolation provided by natural barriers (-)	*Bi* Biosphere dose conversion indicator (Sv/Bq)
Four factors that determine the exposure dose: (1)Radioactivity inventory of the disposed waste (2)Nuclide migration control capability of engineered barriers (3)Isolation provided by natural barriers (4)Biosphere dose conversion factor	Qi: gross radioactivity[Bq]	$Ei = f(\zeta, \eta_i, \lambda_i)$ ζ : leaching rate [-/y] η_i : migration rate [-/y] λ_i : decay constant [-/y] $\eta_i = \frac{Fa + Fd_i}{Fr_i}$ *Fa*: advection parameter [-/y] Fd_i: diffusion parameter [-/y] Fr_i: retardation parameter [-/y]	$Gi = \left(\frac{1}{2}\right)^{\frac{T_{eff}}{T_{1/2}}} g(D)$ $T_{eff,i}$: effective travel time [y] $T_{1/2,i}$: half life [y] g(D): dispersion distance correction term	$Bi = \mu i \cdot C_{B,i}$ μ_i : dose conversion factor [Sv/Bq] $C_{B,i}$: correction factor for dilution, concentration, etc., in the process of migration to the biosphere [-]
Important parameters	(1) Waste type	(1)Activated material leaching ratio (2) Permeability in the low permeability layer (3)Effective diffusion coefficient in the low diffusivity layer (4)Distribution coefficient for migration through engineered barriers (5)Migration ratio through engineered barriers	(1)Distribution coefficient for migration through natural barriers (2) travel distance (3)Effective flow rate (4)Dispersion distance	(1) Dilution volume (2) Concentration coefficient (3) Migration coefficient for food products from lakes and rivers

One-Dimensional Nuclide Migration Modeling for Groundwater Scenarios



- Across different layers from the waste package layer to the bedrock, nuclides migrate by advection, dispersion and diffusion.
- Safety assessment is supported by one-dimensional modeling by GoldSim, in which the volumes of the concrete pit structure, low diffusivity layer and low permeability layer are.
- The uniform aggregate layer represents the backfill, support, lining and EDZ outside the low permeability layer under a single grouping.

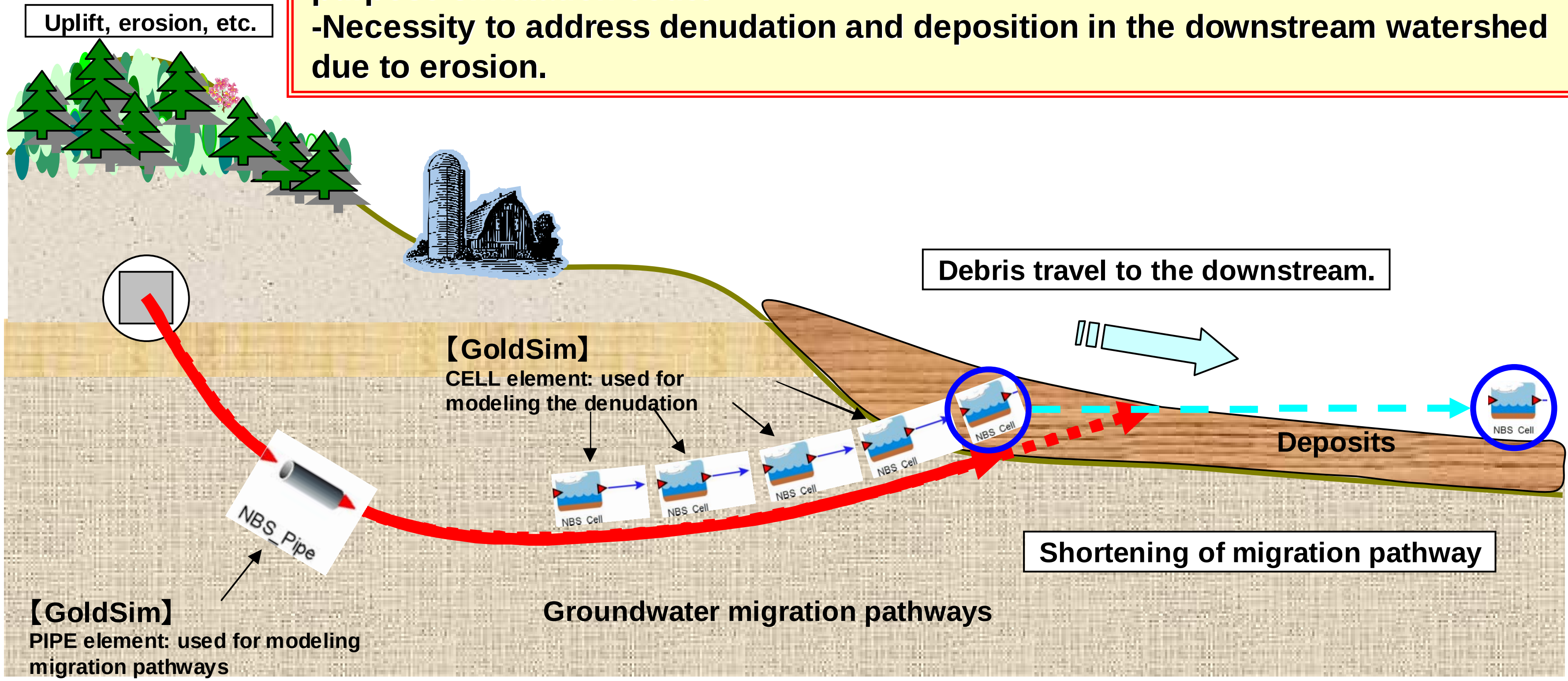


Key technical issues concerning one-dimensional nuclide migration modeling for groundwater scenarios:
- Methods for enabling one-dimensional models to achieve equivalent and conservative representation of nuclide migration across a two-dimensional profile by advection and diffusion
- Modeling of the degradation of engineered barrier properties by aging and of the cracking of concrete

One-Dimensional Nuclide Migration Modeling with the Consideration of Changes in Migration Pathways through Natural Barriers

Key technical issues of addressing changes in migration pathways through natural barriers by one-dimensional nuclide migration modeling:

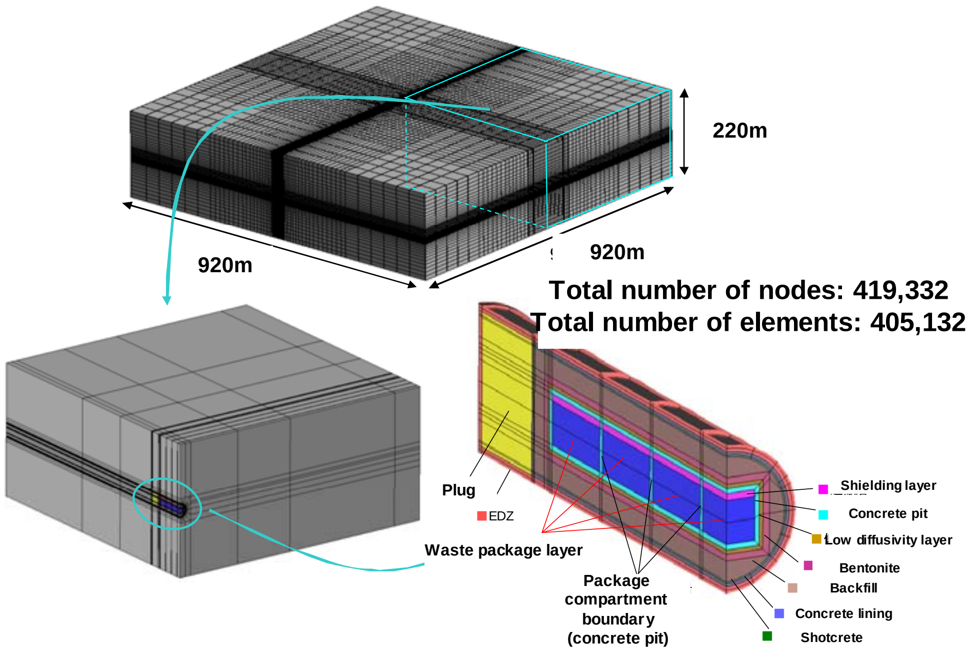
-Spatial changes in migration pathways through natural barriers and the shortening of migration pathways must be represented by changes in the travel length (or time) through natural barriers.
-Appropriateness of modeling by the combination of various elements of general purpose simulation code.
-Necessity to address denudation and deposition in the downstream watershed due to erosion.

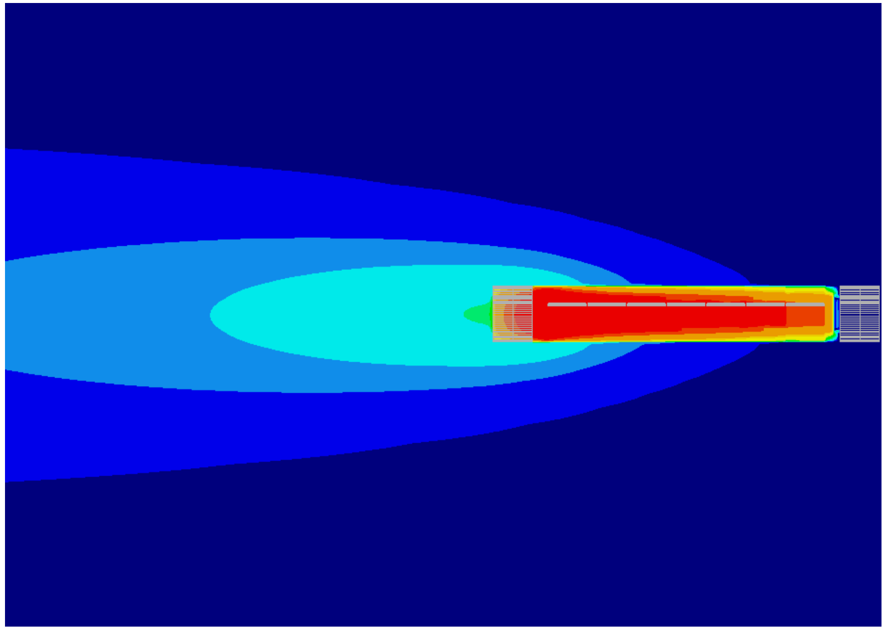


Multidimensional Nuclide Migration Modeling

Key technical issues concerning multidimensional nuclide migration modeling:

- Pursuit of higher accuracy by the improvement of numerical solution methods (better algorisms for lesser numerical dispersion values)
- Appropriateness of one dimensional modeling of cases in which the line of hydraulic gradient does not perpendicularly go across the length of cavern
- Modeling of entire cavern (assessment of the independency of each cavity; assessment of the probability of interconnection due to EDZ and assessment also of the plug performance)





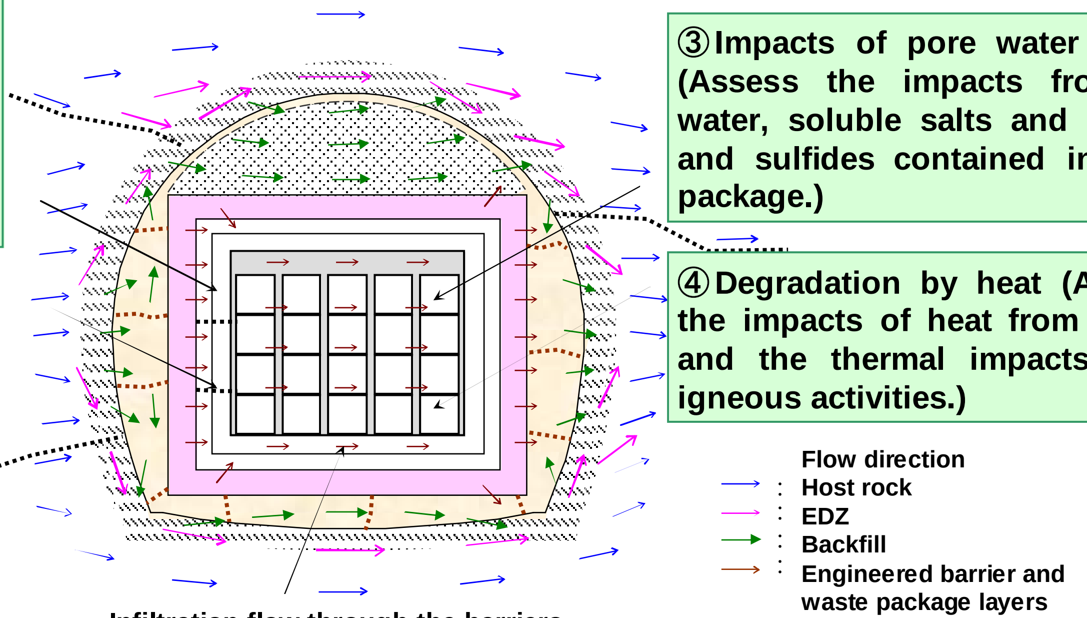
Migration behavior of radioactive materials in the presence of groundwater flow parallel to the length of cavern

In a cavern that does not have partitions, advection and diffusion may cause the radioactivity concentration to increase at the end of cavern.

Ⅴ.3 Safety R&D on Protection Capability Assessment of Engineered Barriers Assessment of Degradation of Cement Component(s)s

① Leaching of hydrates from cement and the formation of secondary mineral products (Assess the impacts of the formation of pores due to leaching and the impacts of the swelling of secondary mineral products.)

② Appearance and growth of cracks due to changes in the stress field or due to degradation (caused mainly by the swelling of reinforcing bars and waste containers due to corrosion)



Infiltration flow through the barriers

③ Impacts of pore water quality (Assess the impacts from salt water, soluble salts and nitrides and sulfides contained in waste package.)

④ Degradation by heat (Assess the impacts of heat from waste and the thermal impacts from igneous activities.)

Make use of relevant materials such as: Japan Society of Civil Engineers "Guides for the Setting of Nuclide Migration Assessment Parameters for Groundwater Scenarios in the Safety Assessment for Sub-surface Depth Disposal" (June 2008).

Safety R&D on Protection Capability Assessment of Engineered Barriers
Assessment of Degradation of Bentonite Component(s)

Photo: Bentonite deposit covered by the natural analogue study

Bentonite component (s) degradation processes that require attention:

①The loss of compaction and low permeability feature of the bentonite layer with the fall of earth pressure due to uplift, erosion, etc.
→ JNES studies various properties of bentonite layers in exposed bentonite deposits (natural analogues).

② Loss of the low permeability feature due to chemical transformation (into Ca-type bentonite)

Safety R&D on Protection Capability Assessment of Engineered Barriers
Understanding of the Ultimate Characteristics of Cement and Bentonite

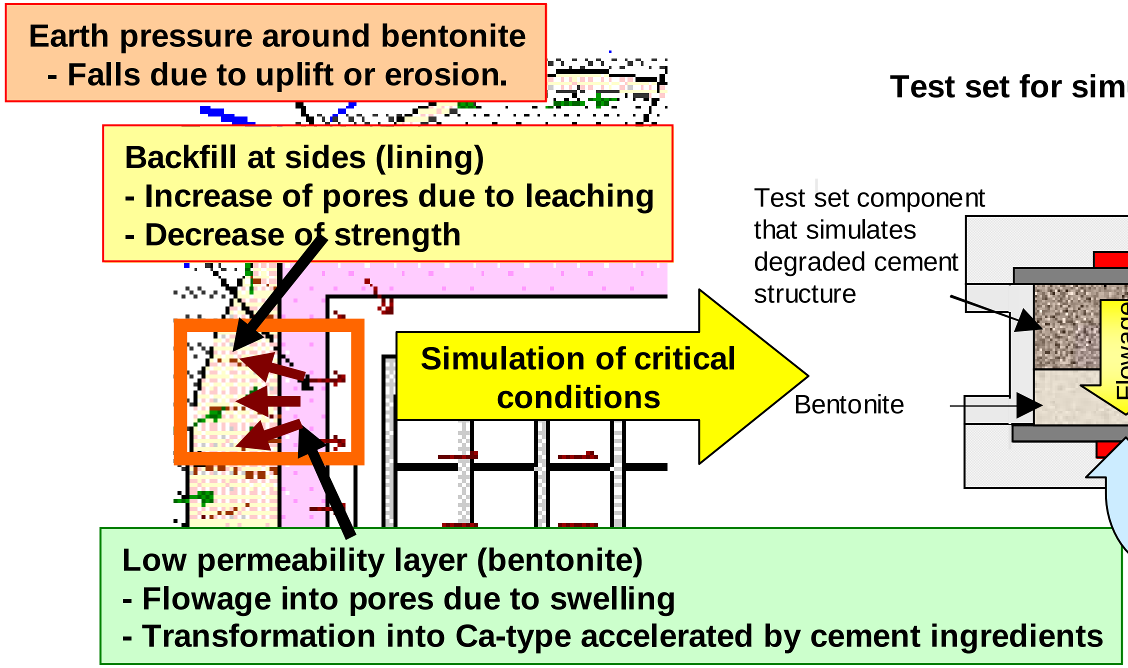
Ultimate characteristics: inherent characteristics that can be still expected from bentonite under severe conditions produced by the combination of multiple degradation processes that should be assumed:

- Loss of compaction due to the flowage of bentonite into the pore of degraded cement component(s)s

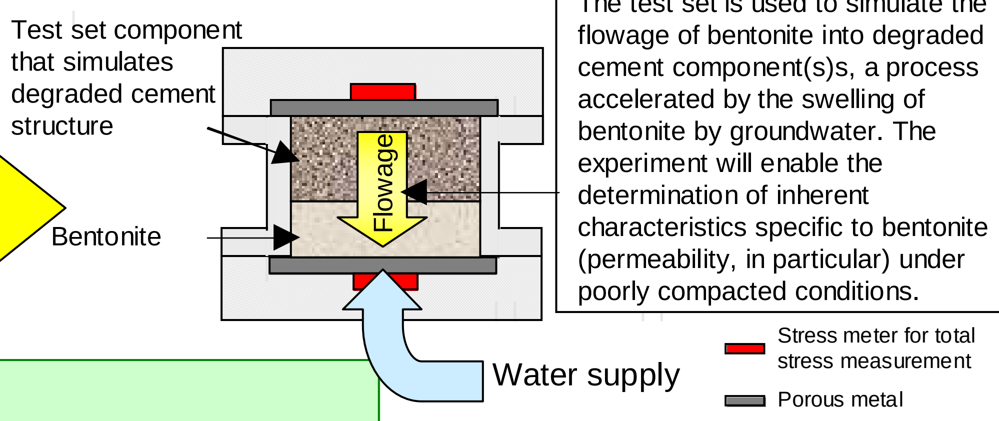
- Fall of earth pressure due to uplift or erosion, resulting in the loss of constraint on the swelling of bentonite

- Chemical degradation of bentonite (transformation into Ca-type bentonite)

[JNES is now conducting a column test (FY2009-2010).]



Test set for simulating the flowage of bentonite

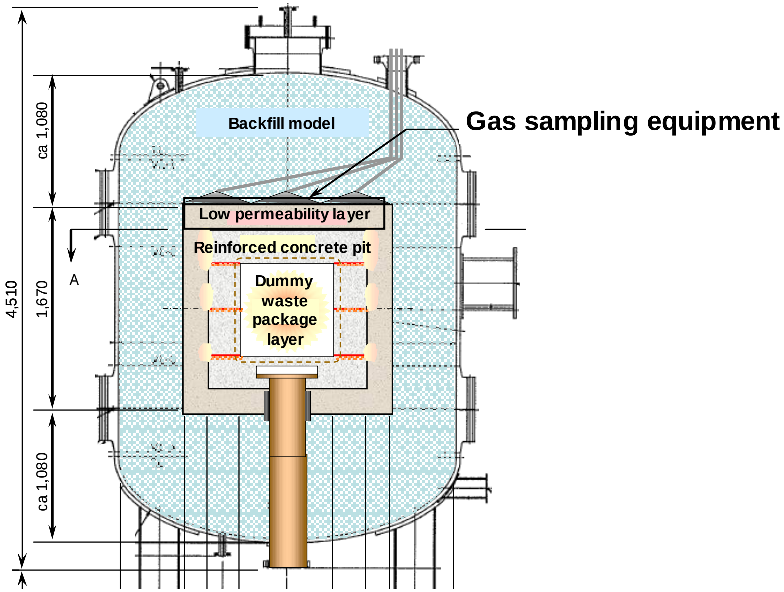


The test set is used to simulate the flowage of bentonite into degraded cement component(s)s, a process accelerated by the swelling of bentonite by groundwater. The experiment will enable the determination of inherent characteristics specific to bentonite (permeability, in particular) under poorly compacted conditions.

Assessment of Engineered Barrier Performance in the Transient Period
Experiments for the Verification of Safety Margins for Engineered Barriers

- Engineering-scale (about 1/5) model (more than 100years ➞about 2)
- Understanding of resaturation and gas migration behaviors in the low permeability layer

Test set overview (before coating)



Concept of the three-dimensional test set (1/5 scale model)

The following should be verified by this experiment for the verification of safety margins for engineered barriers using an engineering-scale model:

1. Stable preservation of the low permeability property

→ Using the engineering-scale model, it should be verified that the whole layer swells uniformly and the intended low permeability property is achieved without much dependence on local-scale properties.

2. Formation of gas breakthrough pathways by the growing gas pressure

→ The stress from gas pressure may concentrate at corners of the low permeability layer, producing breakthrough pathways even at a relatively low gas pressure. It should be verified that such will not spoil the integrity of engineered barriers.

3. Restoration of low permeability after the release of gas

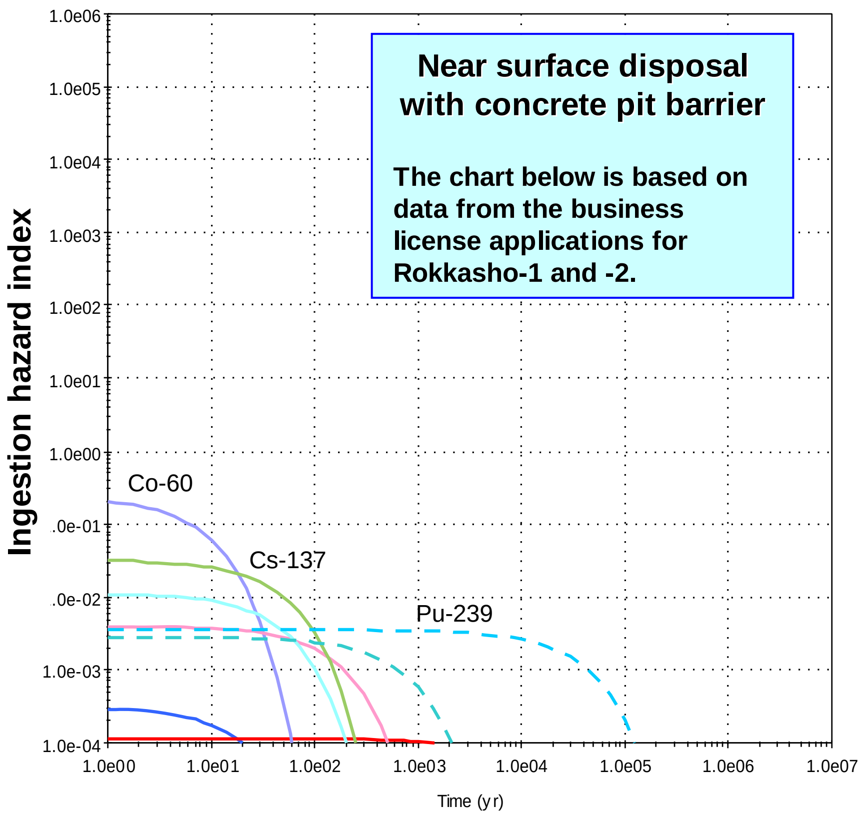
→ It should be verified that breakthrough pathways are closed again and the low permeability property is restored due to the self-sealing property of bentonite.

Ⅵ. Prospective Activities of Regulation Support R&D in the Future

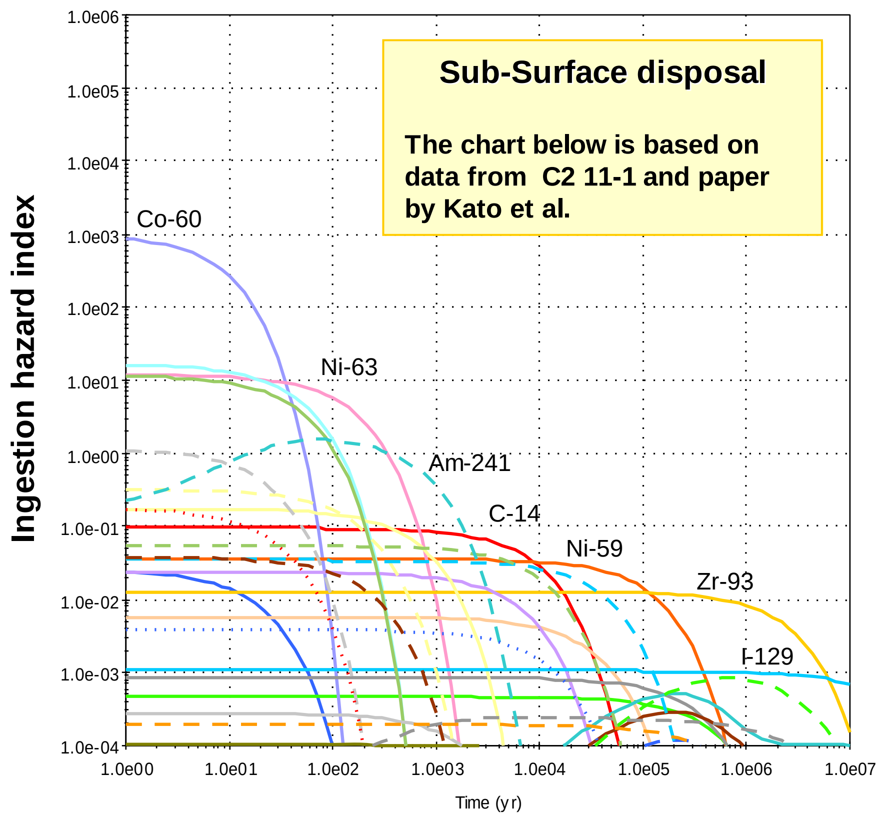
1. Safety Regulation According to the Level of Potential Hazard from Waste
2. Basic Design Reliability and Repository System Robustness
3. Ensuring of Total Safety Performance Taken in Consideration of Natural Barrier Performance
4. Preparation for Regulation Process after Safety Review

Safety Regulations According to the Level of Potential Hazard from Radioactive Waste

Based on the risk-informed approach, the safety regulations demand trench disposal, concrete pit disposal or sub-surface disposal depending on the level of potential hazard from each specific type of radioactive waste.



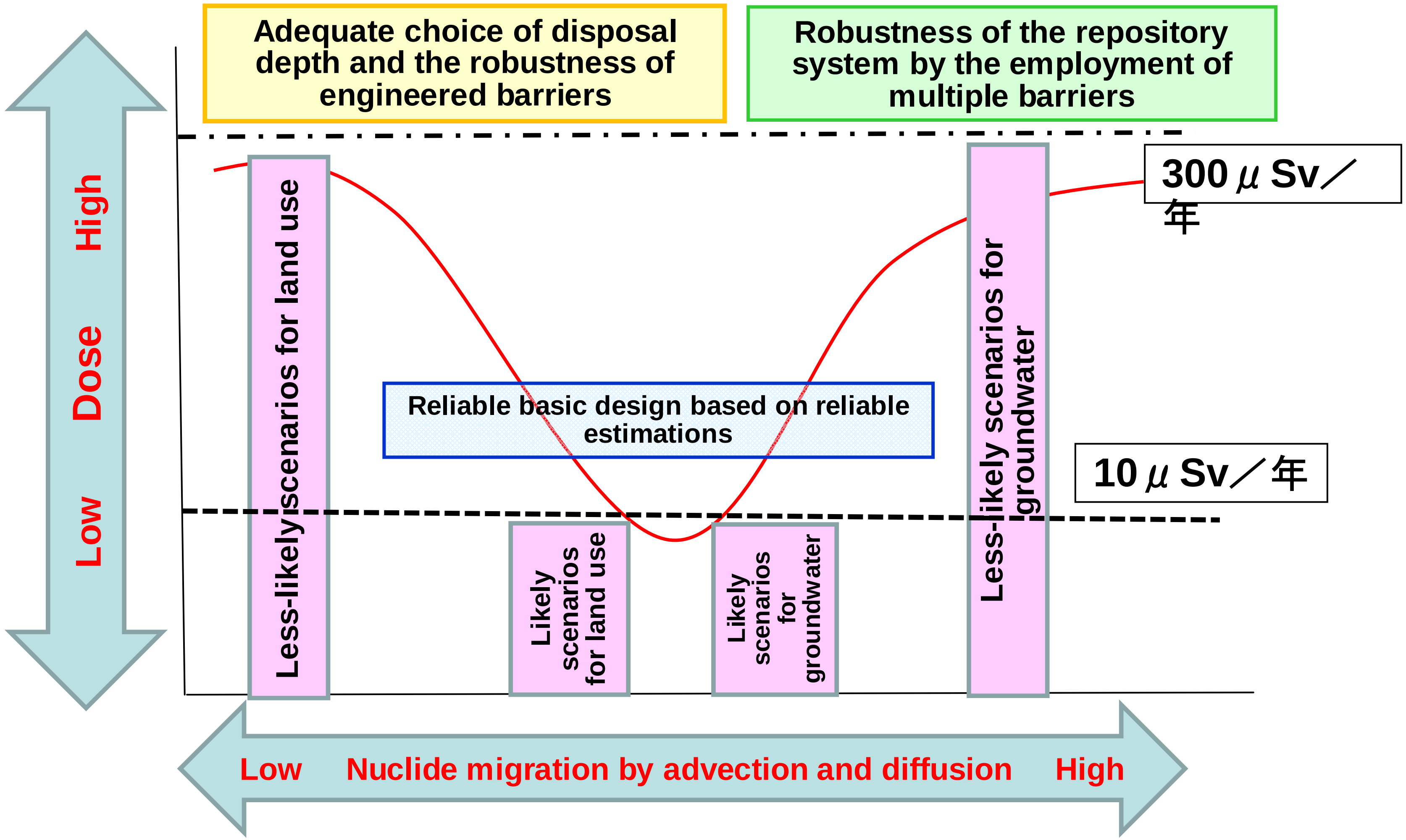
The contamination level of operational waste is extremely low because fuel failures are rare in recent light water reactors and the reactor water contamination level is low.



Key nuclides in waste for sub-surface disposal are difficult to measure. It is important to improve the accuracy of estimation based on calculations about activation.

JNFL: Business License Application for Rokkasho Low-Level Radioactive Waste Disposal Center. Jan. 1997
FEPC : Quantities and Radioactivity Concentration Levels of Waste for Sub-Surface Disposal (C2 11-1; Sep. 24, 2008)
Kato et al.,: Current Status of Technical Confidence Building for Sub-surface Disposal (Journal of Nuclear Fuel Cycle and Environment Vol13 No.1 , P49-64,2006)

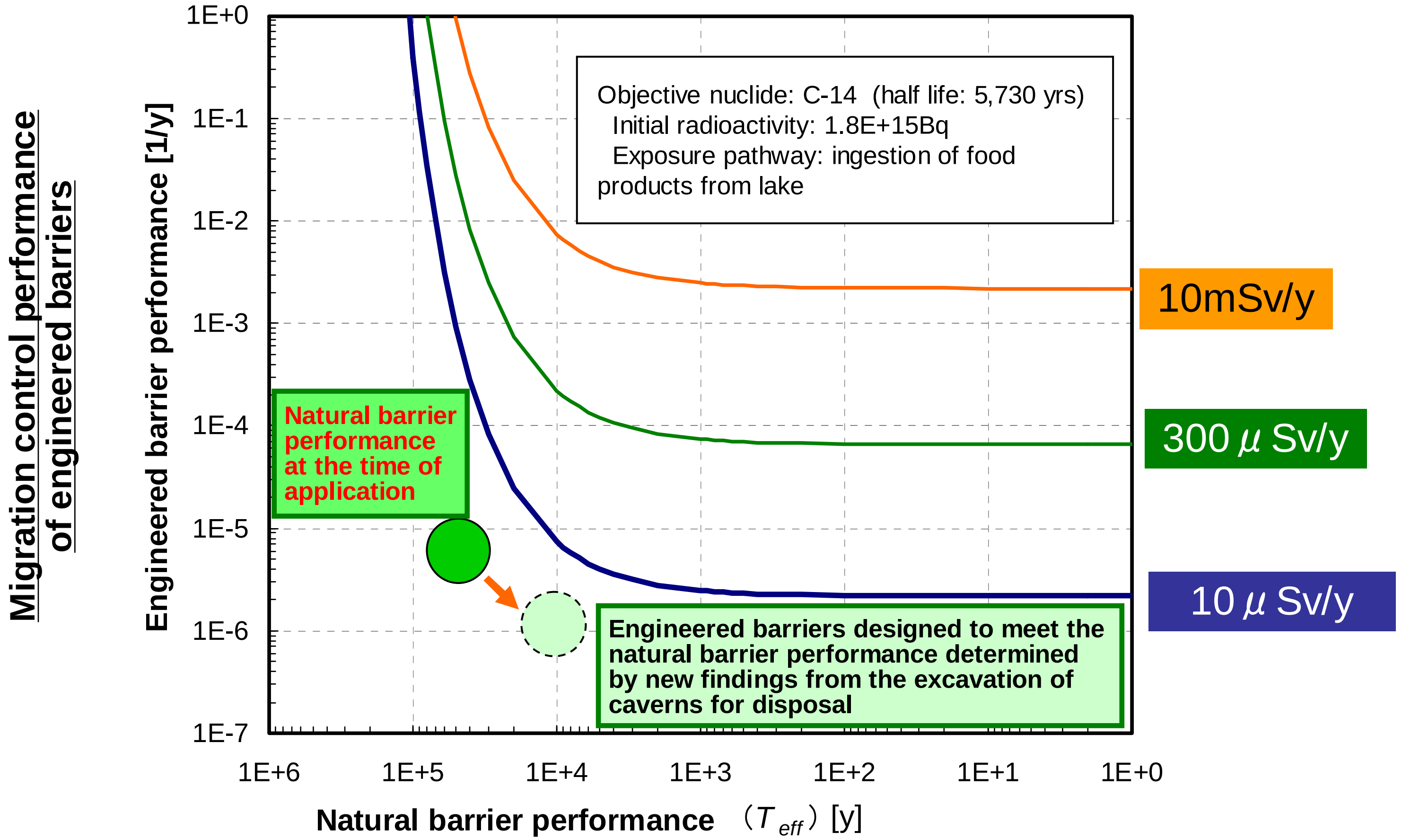
Basic Design Reliability and Repository System Robustness



The overall safety should be ensured by developing the basic design based on reliable predictions on highly probable and normally expected events with conservative approaches to both sides contradictory characteristics

Ensuring of Total Safety Performance Taken in Consideration of Natural Barrier Performance

Example of engineered-natural barriers combination that meets the standard dose values and ensuring of total safety performance



Migration performance of natural barriers

Preparation for Regulation Process after Safety Review

	Waste Package	Engineered barriers	Natural barriers	Biosphere
Safety performance indicator	Total radioactivity inventory Qi: (Bq)	Migration control capability of engineered barriers: Ei (1/y)	Isolation capability of natural barriers: Gi (-)	Biosphere dose conversion factor: Bi (Sv/Bq)
Major factors that impact safety	Radioactivity inventory -Total radioactivity -Radioactivity concentration	Waste characteristics - Leaching rate Migration control capability of engineered barriers - Control of diffusion, control of permeation, and retardation of nuclide migration	Retardation of nuclide migration - Groundwater travel time - Retardation function	Dose conversion - Dose conversion factor - Correction coefficient for dilution and concentration in the process of migration in the biosphere Prevention of specific human activities, etc. - Phased control
Confirmation by the regulatory authorities	Waste package confirmation (JNES)	Facility examination (NISA, with the partial involvement of JNES)	Facility examination (NISA, with the partial involvement of JNES)	Approval of the operational safety program
Confirmation procedure	- Waste package confirmation procedure	- Facility examination procedure	- Facility examination procedure	- Monitoring procedure

END

Thank you for your attention.