Design of the Repository for High Level Waste in Sweden

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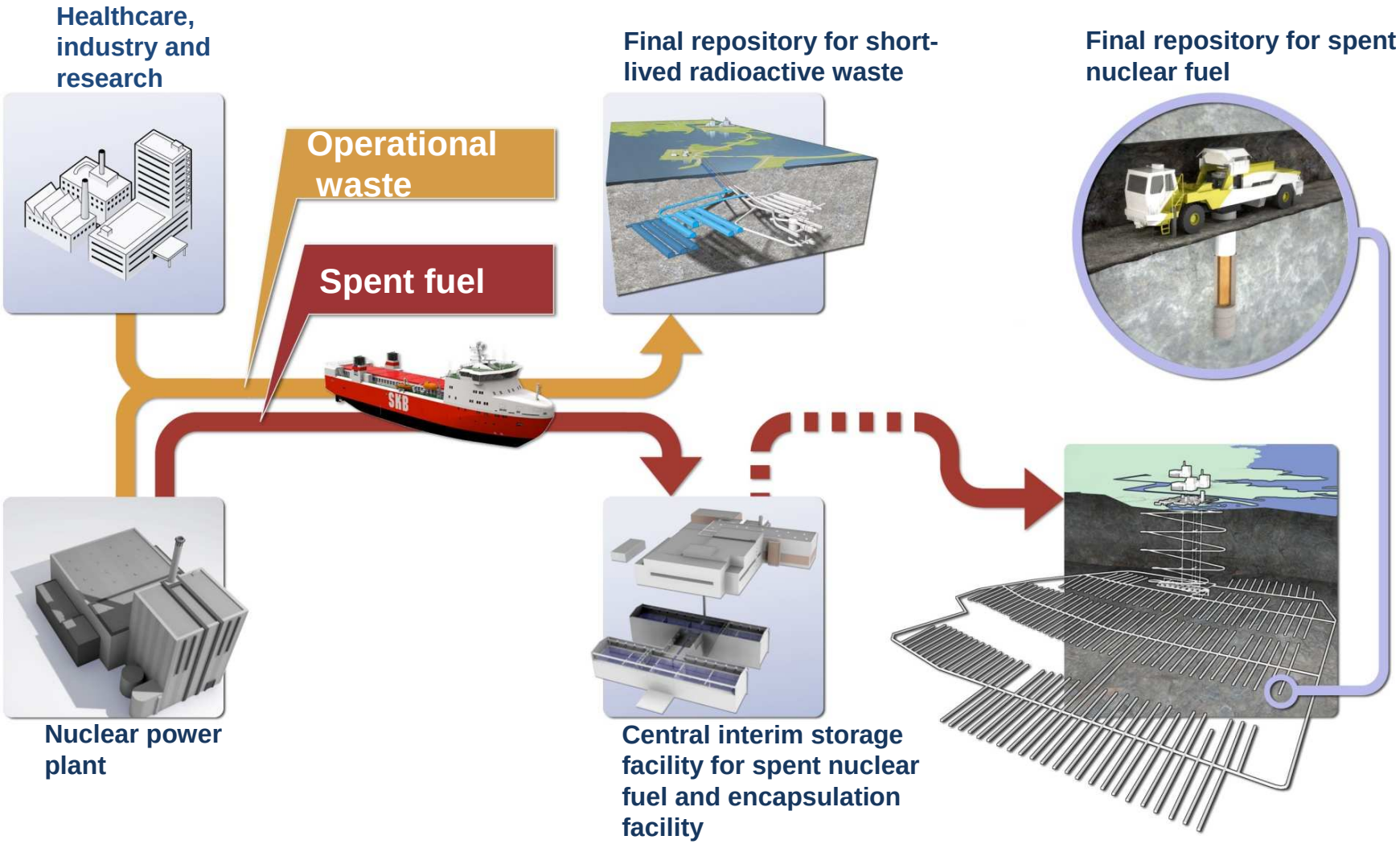
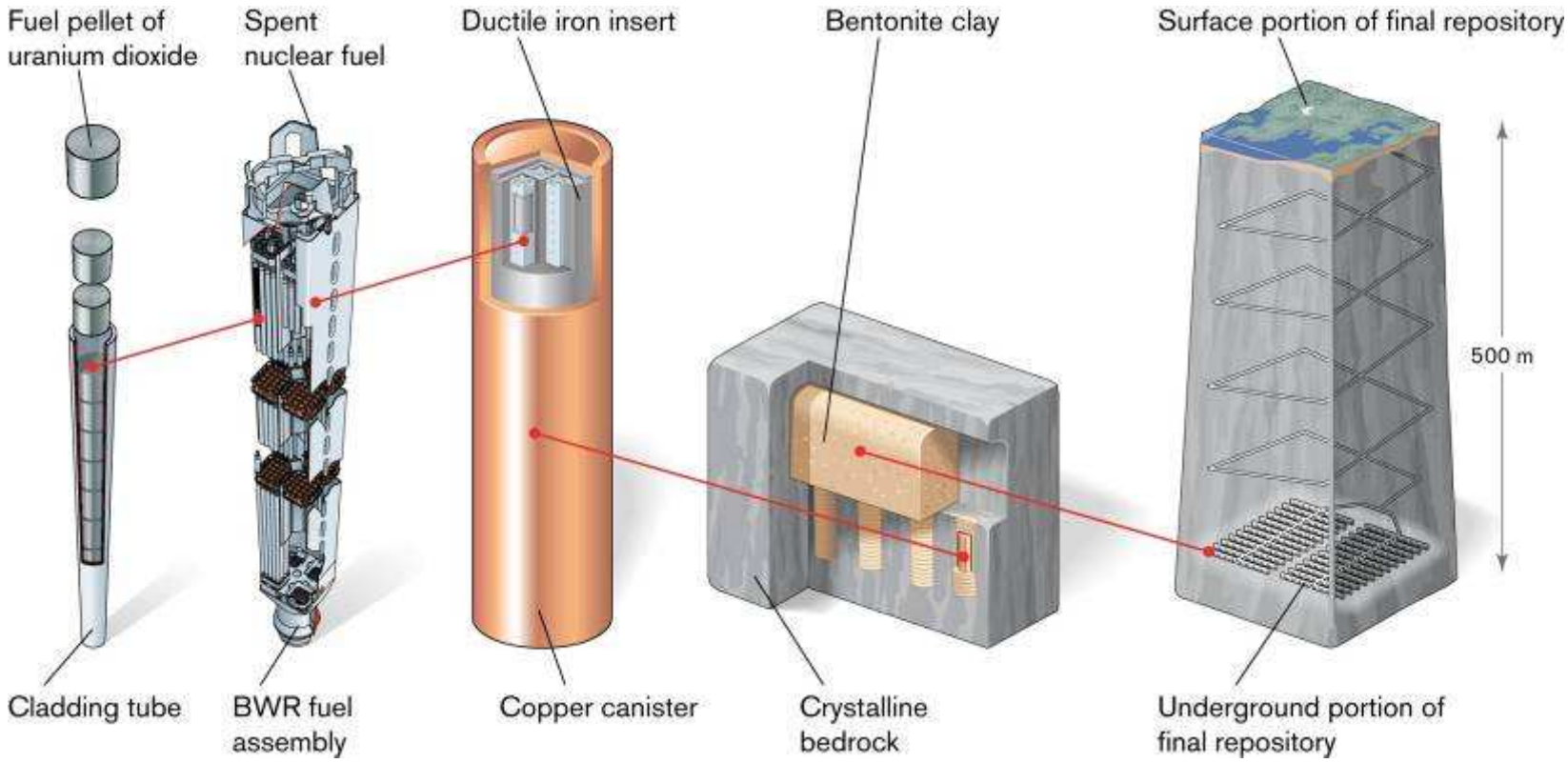
Content

1. **Introduction**. The system, the facility (construction and operation) and the repository (post-closure stage)
2. Design Requirements and Design strategy
3. Summary of current design results
4. Site selection and overview of current layout
5. Some highlights of current activities
6. Concluding remarks

The Swedish system

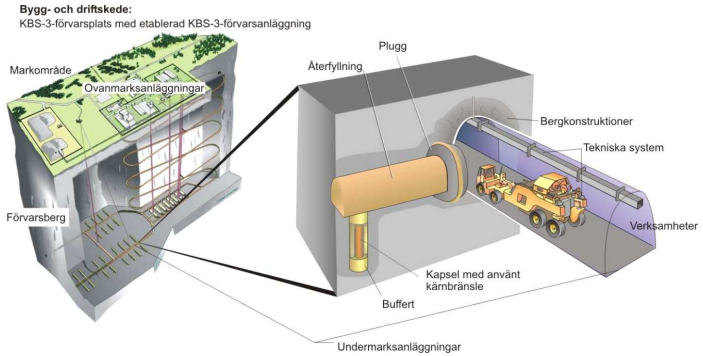


The KBS-3 method



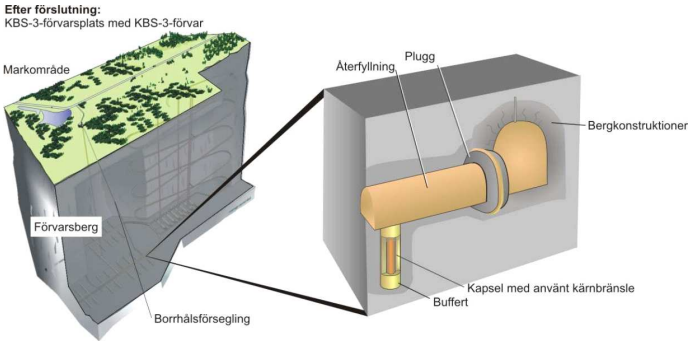
Definition

Final repository facility



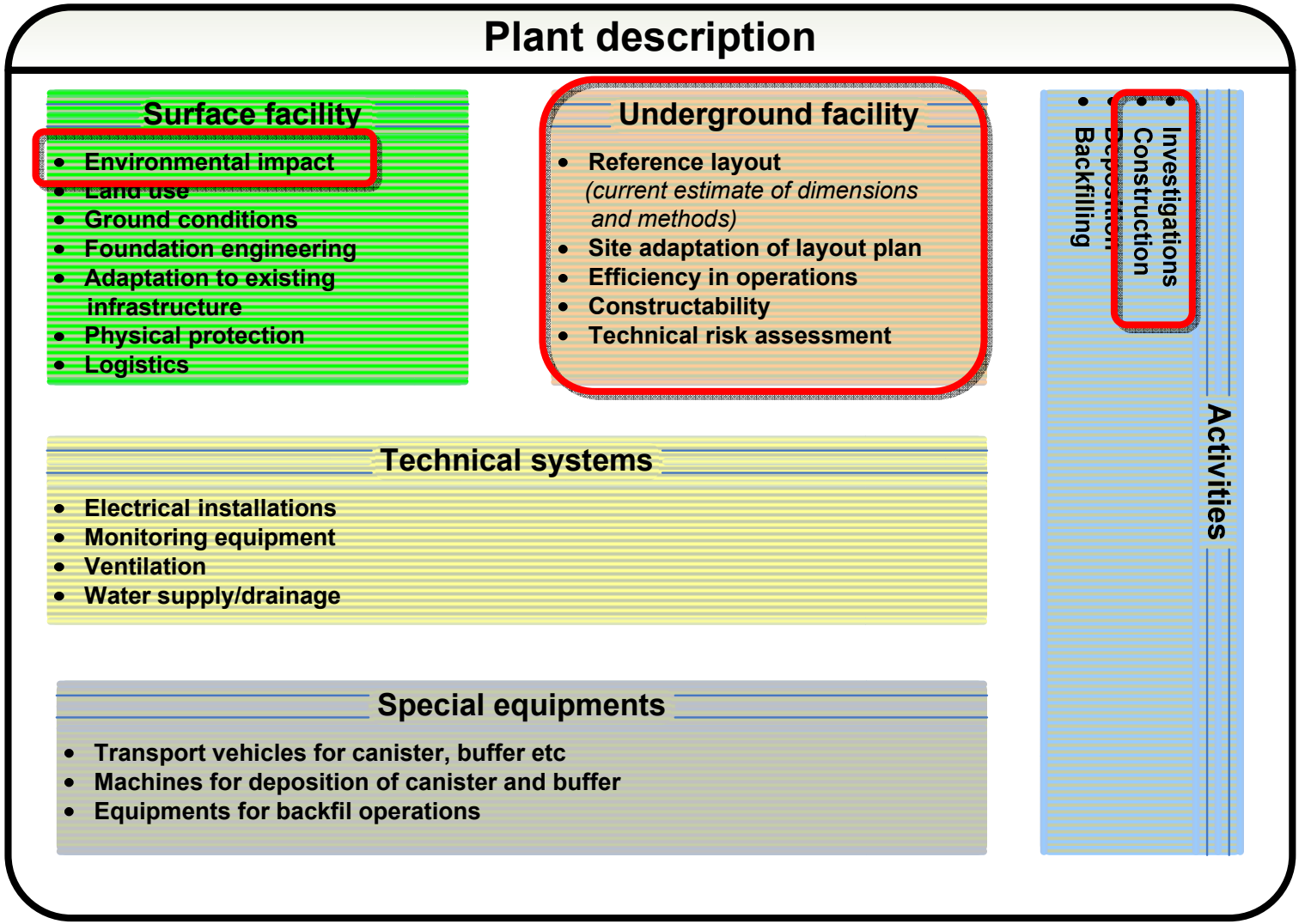
Comprises the caverns, constructions and buildings above and below surface required to produce the final repository and operate the final repository facility.

Final repository

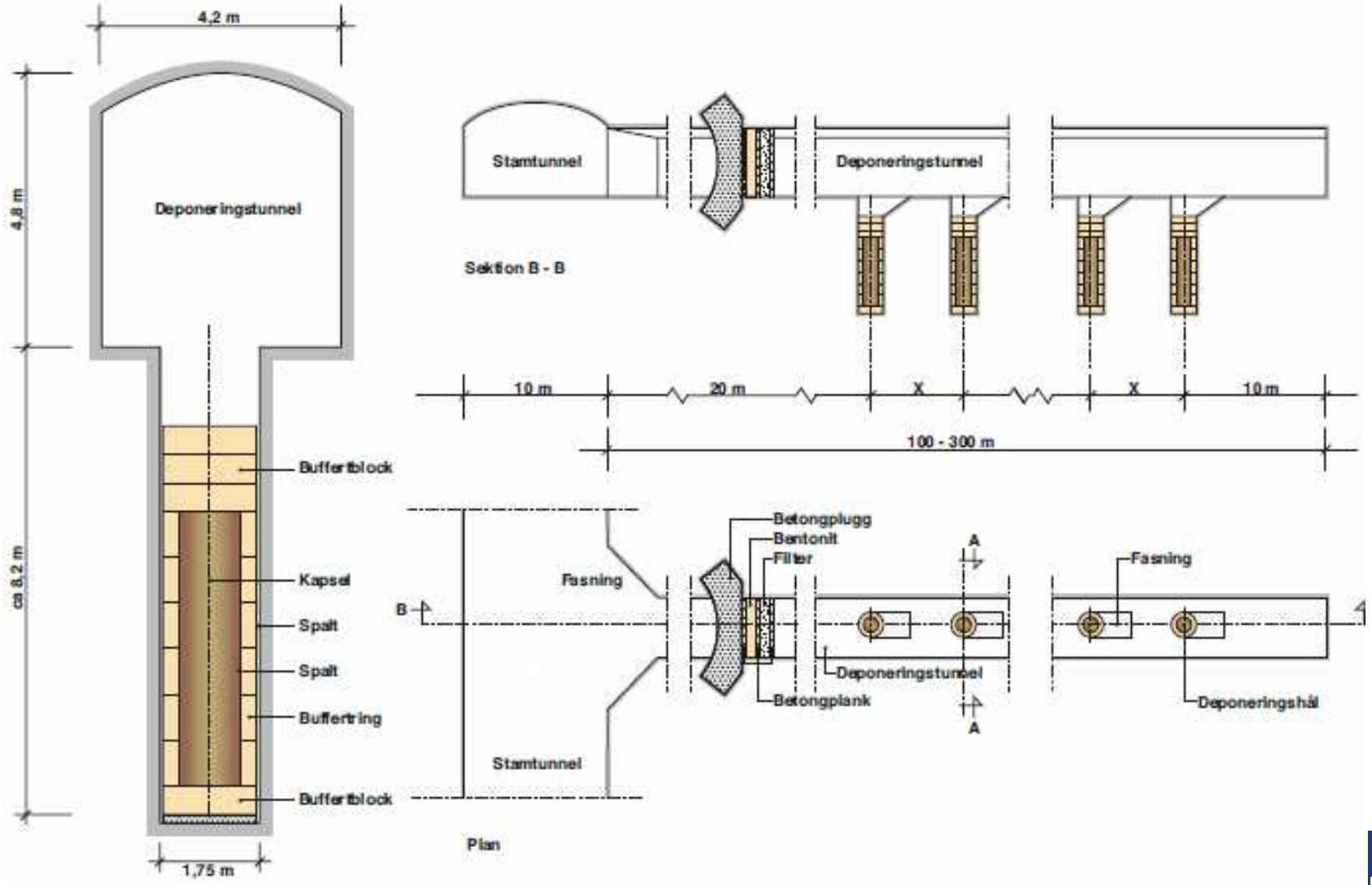


Comprises the rock at the repository site, the canisters with spent fuel, buffer, backfill, closure and stray materials left in the repository at deposition, backfill and closure.

Design of the Repository covers much more than the Underground Facility



Deposition tunnel and deposition hole



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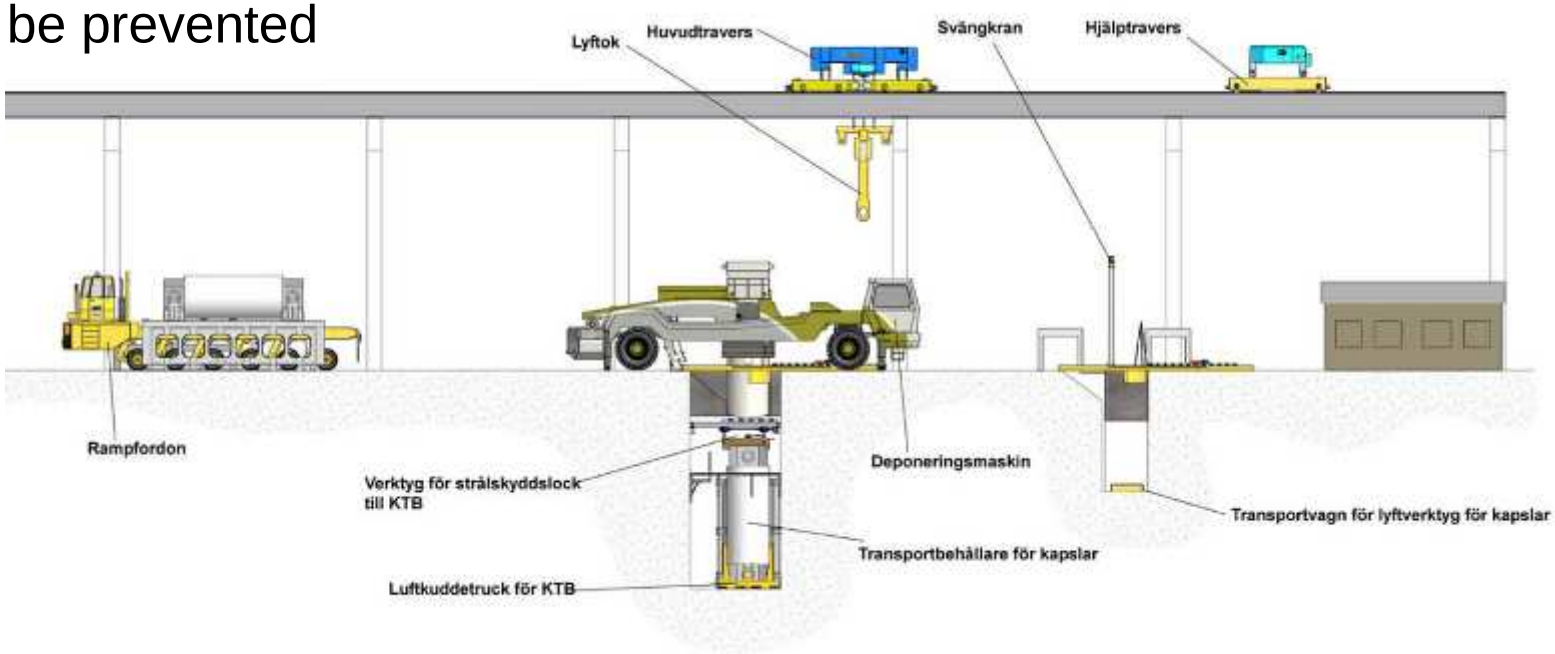
The overall framework for design of Final Repository for Spent Fuel

- Nuclear safety and radiation protection requirements to protect human health and the environment against the harmful effects of radiation
- Design of the facility and activities so that radiological accidents can be prevented



Waste characteristics

- **Fuel** Origin
  - From the 12 Swedish nuclear power plants, BWR and PWR
  - Small amounts of MOX
  - Small amounts from research and early nuclear power (Ågesta)
- Quantity of spent fuel, totally equal to **8000** metric tons (calculated as uranium)

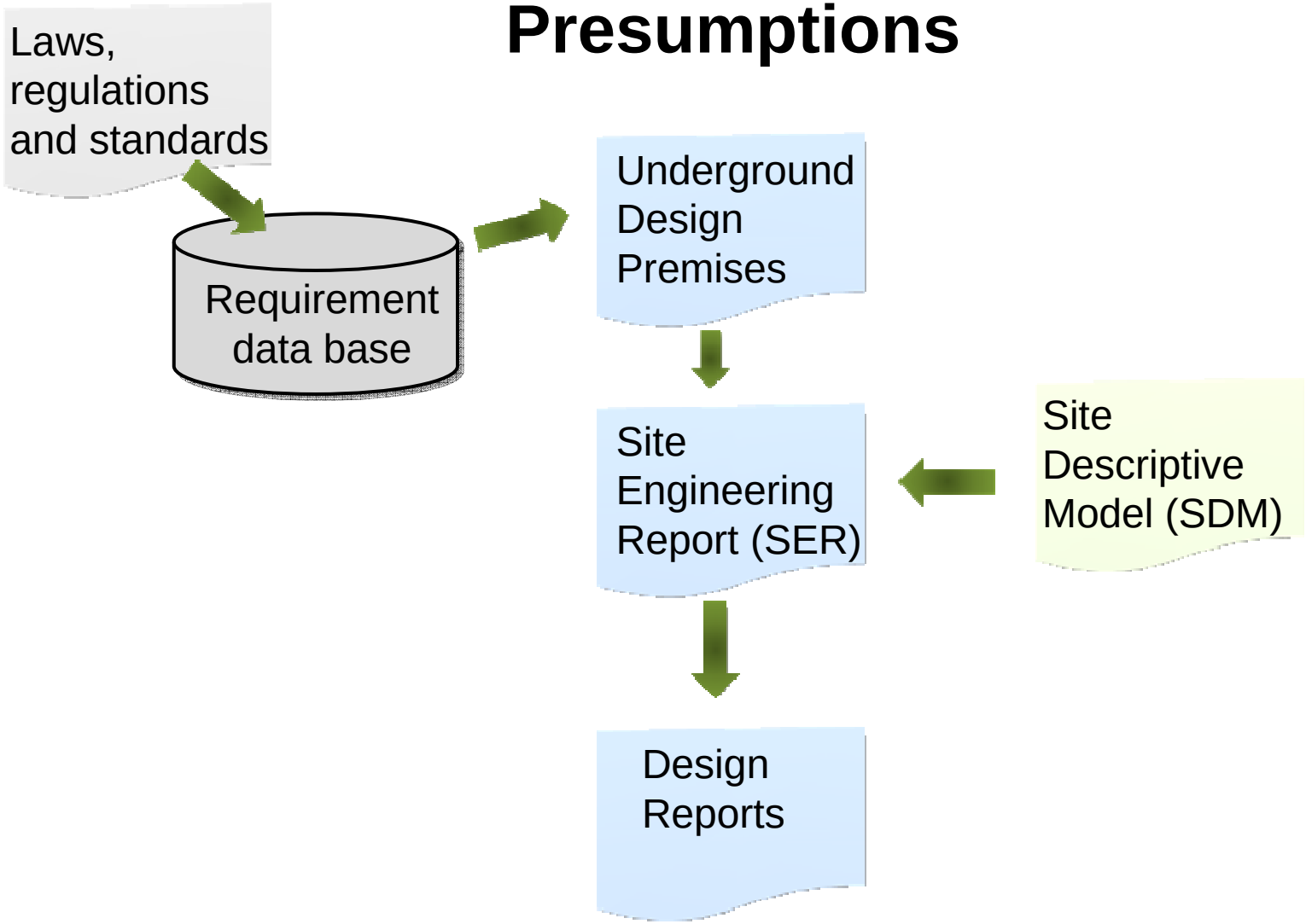
Canister

- 5-cm thick copper corrosion barrier and a load-carrying cast-iron insert.
- Maximum power when canister filled **1700 W**
- Sealed containment for the fuel
- Free of contamination
- Weight; **24 600 kg** (BWR)
- Estimated amount of canisters; **ca 6000**

Summary of design requirements

- **General**:
  - KBS 3 method
  - 6000 canisters, thermal load 1700 W/canister
  - Sealed containment, free of contamination
  - Facility depth at 400 – 700 m depth
  - Step-wise development of deposition areas parallel to disposal
- **Requirements based on long term safety**
  - meet the temperature criterion that the temperature in the buffer is not allowed to exceed 100 ℃
  - develop the layout in suitable rock domains (fracturing and occurrence of ground water)
  - avoid larger deformation zones that may cause a seismic risk to the repository due to post-glacial earthquakes
- **Account for site conditions**, including proposed depth for the Final Repository
- **Efficiency in operations**

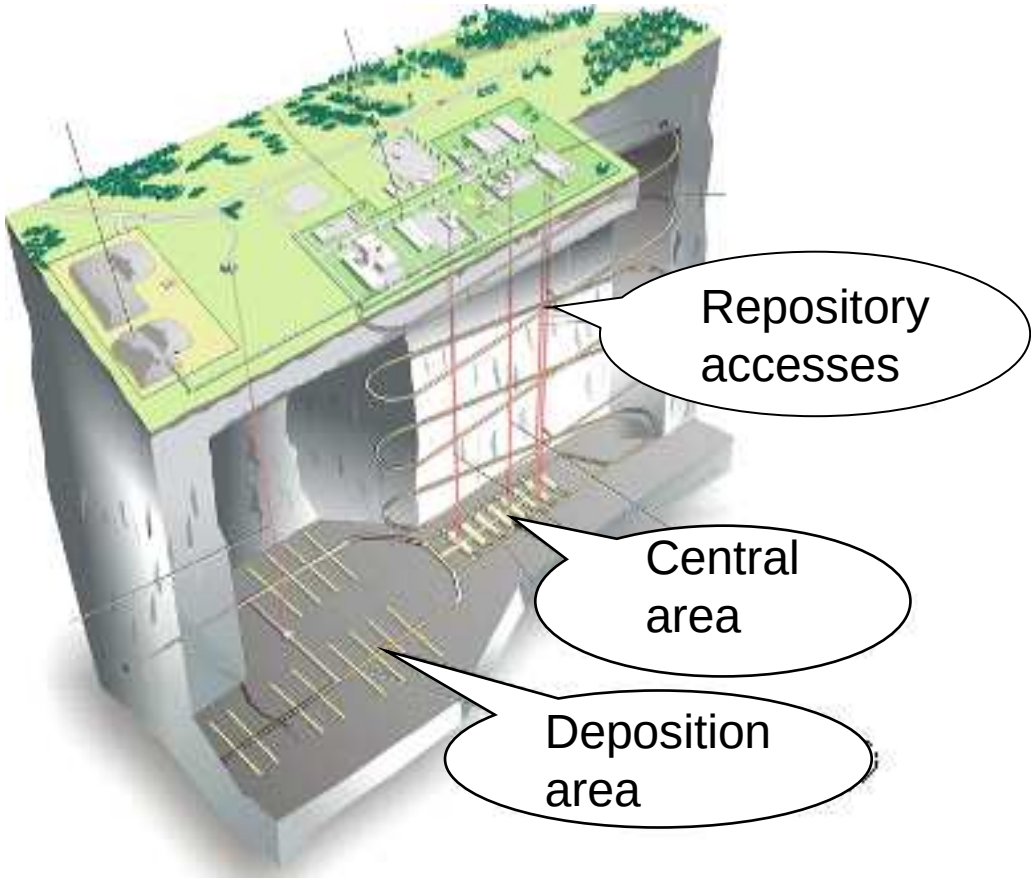
Overview of Design Requirements and Site Presumptions



Important documents

Functional components

- SER divide the Final Repository in the functional areas Access routes, Central area and Deposition area.
- There may be different requirements on different Functional areas



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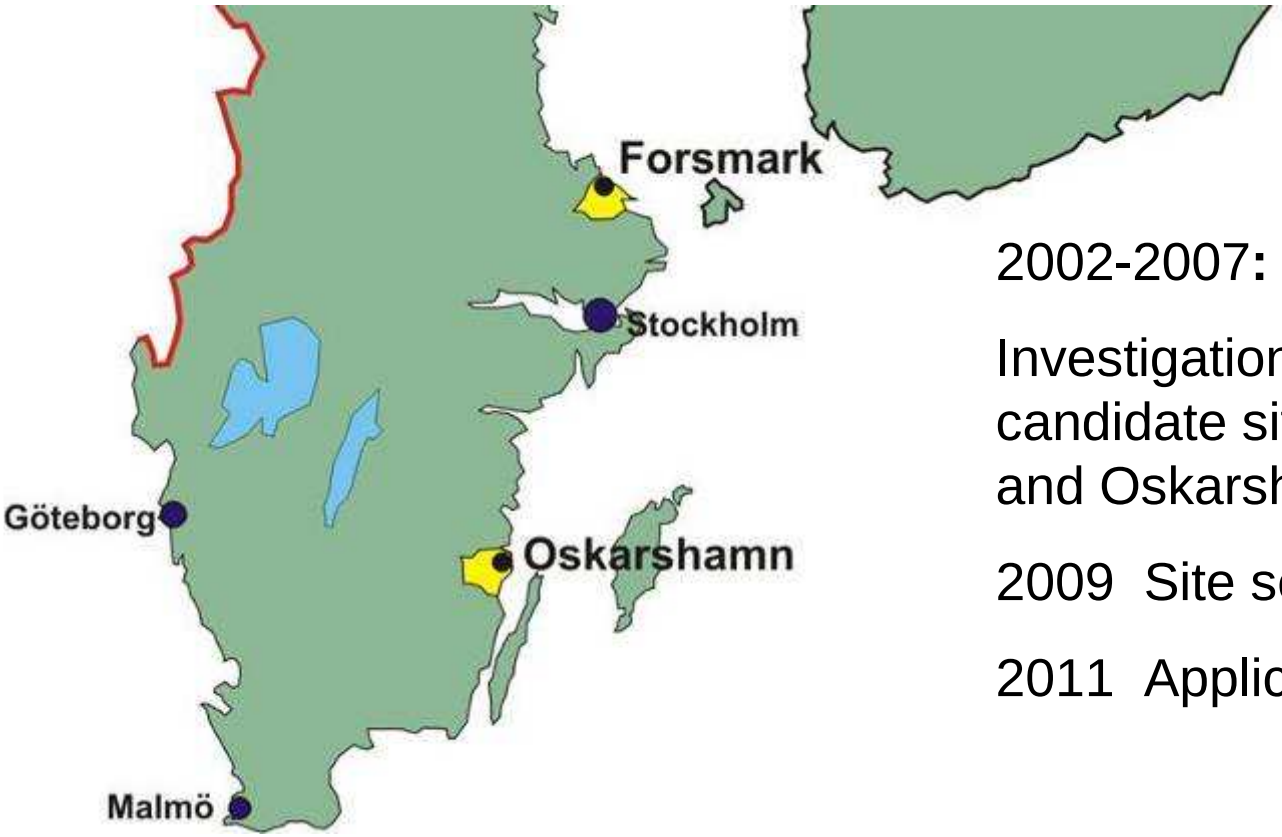
Site selection and application for a repository for spent nuclear fuel in Sweden had to be based on site investigations from the surface

The investigation phase included also ***preliminary design***, safety assessment and environmental impact assessment studies



2002-2007**:**

Investigations of two candidate sites: Forsmark and Oskarshamn/Laxemar

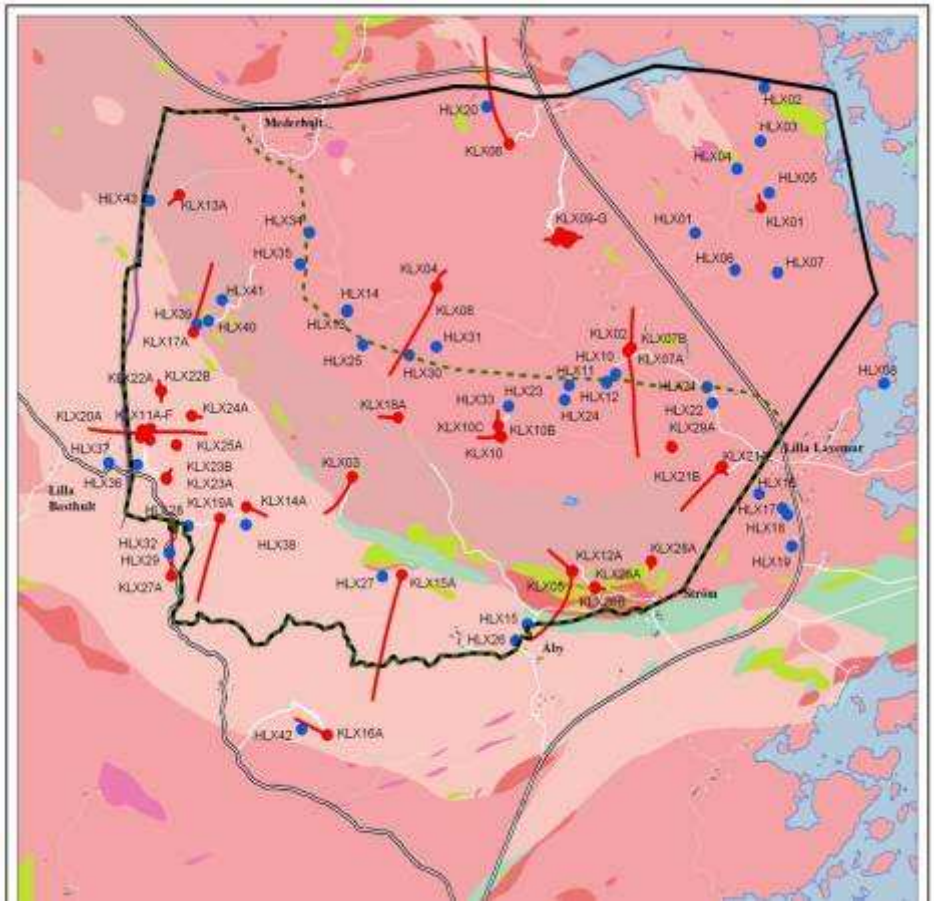
2009 Site selection

2011 Application

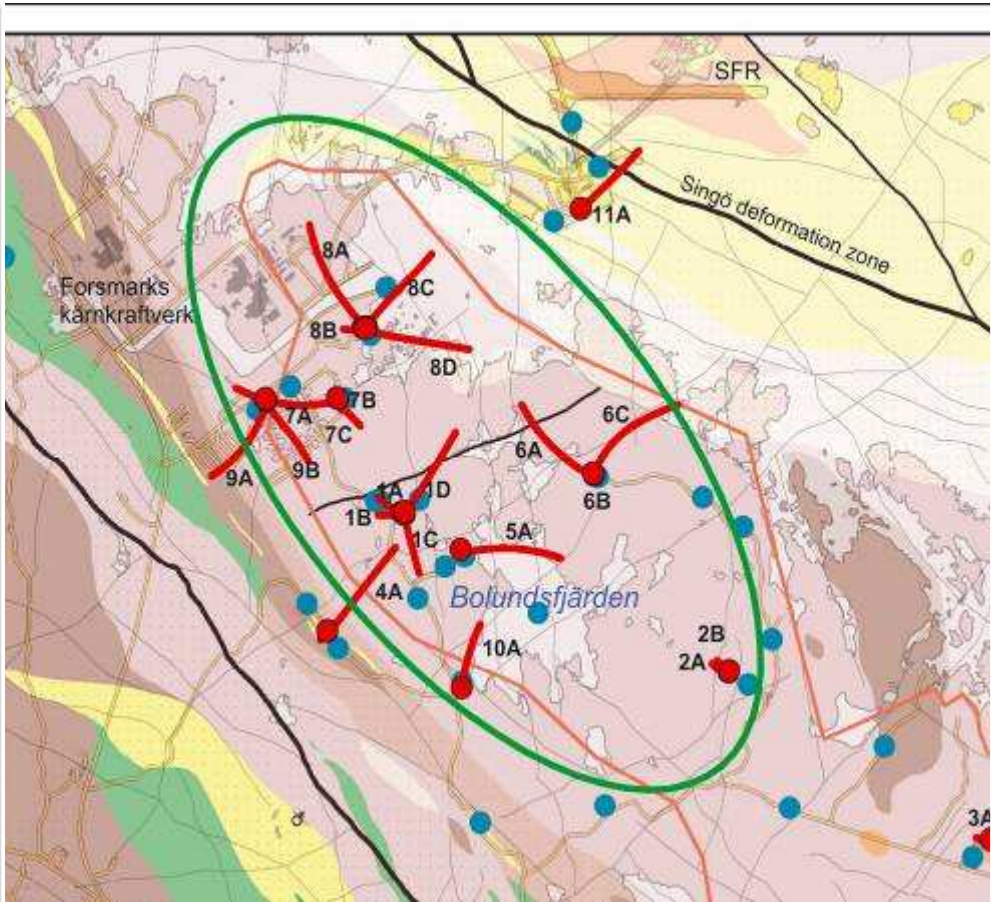
Our sites (crystalline rock in the Baltic Shield)

Comprehensive investigations and evaluations were carried out at both sites

Laxemar



Forsmark



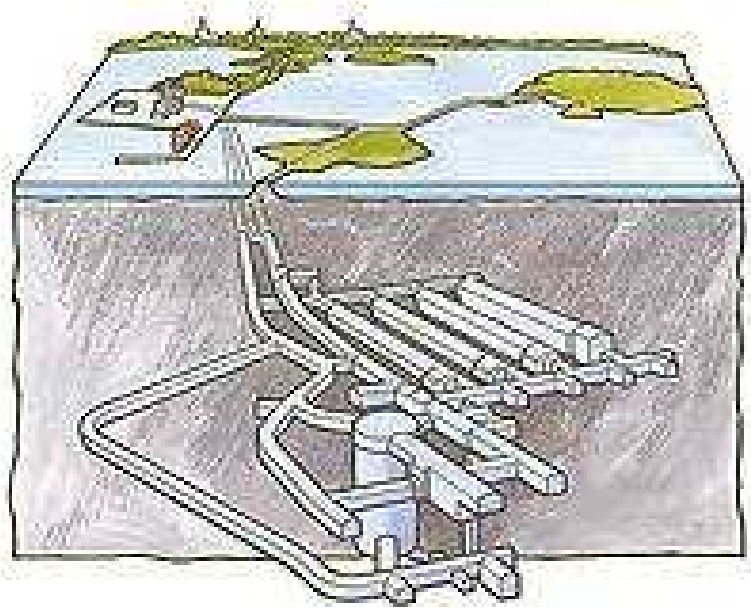
Construction experiences from both sites

Laxemar:

- **Close to Äspö HRL (depth to 450 m)**
- **Clab facility**
- **Power plants**

Forsmark:

- **Close to SFR facility (depth to 150 m)**
- **Power plants**



Layout overviews

Laxemar

Forsmark

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Forsmark

Repository footprint area 3,6 km^2

Facility depth> 450 m

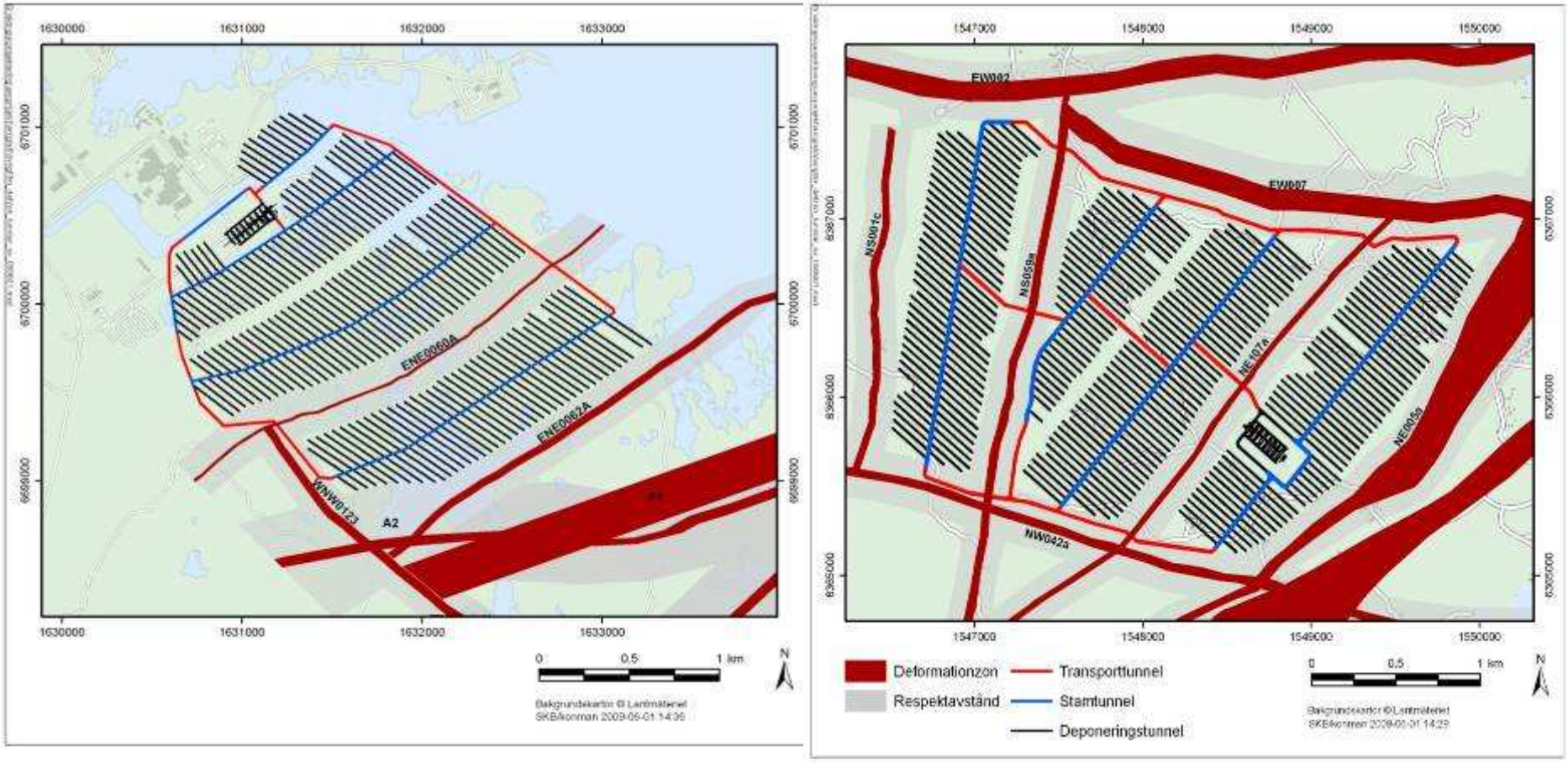
Excavated volumes at repository level: 1.736x10^3 m^3

Laxemar

Repository footprint area 5,7 km^2

Facility depth > 500 m

Excavated volumes at repository level: 2,594x10^3 m^3



SKB's siting factors

Contribution from Design

Safety related site characteristics

- Bedrock composition and structure
- Future climate
- Rock mechanical conditions
- Groundwater flow
- Groundwater composition
- Retardation
- Biosphere conditions
- Overall site understanding

Technology for execution

- Flexibility
- Technical risks
- Technology development needs
- Functionality, operational aspects
- Synergies
- Costs

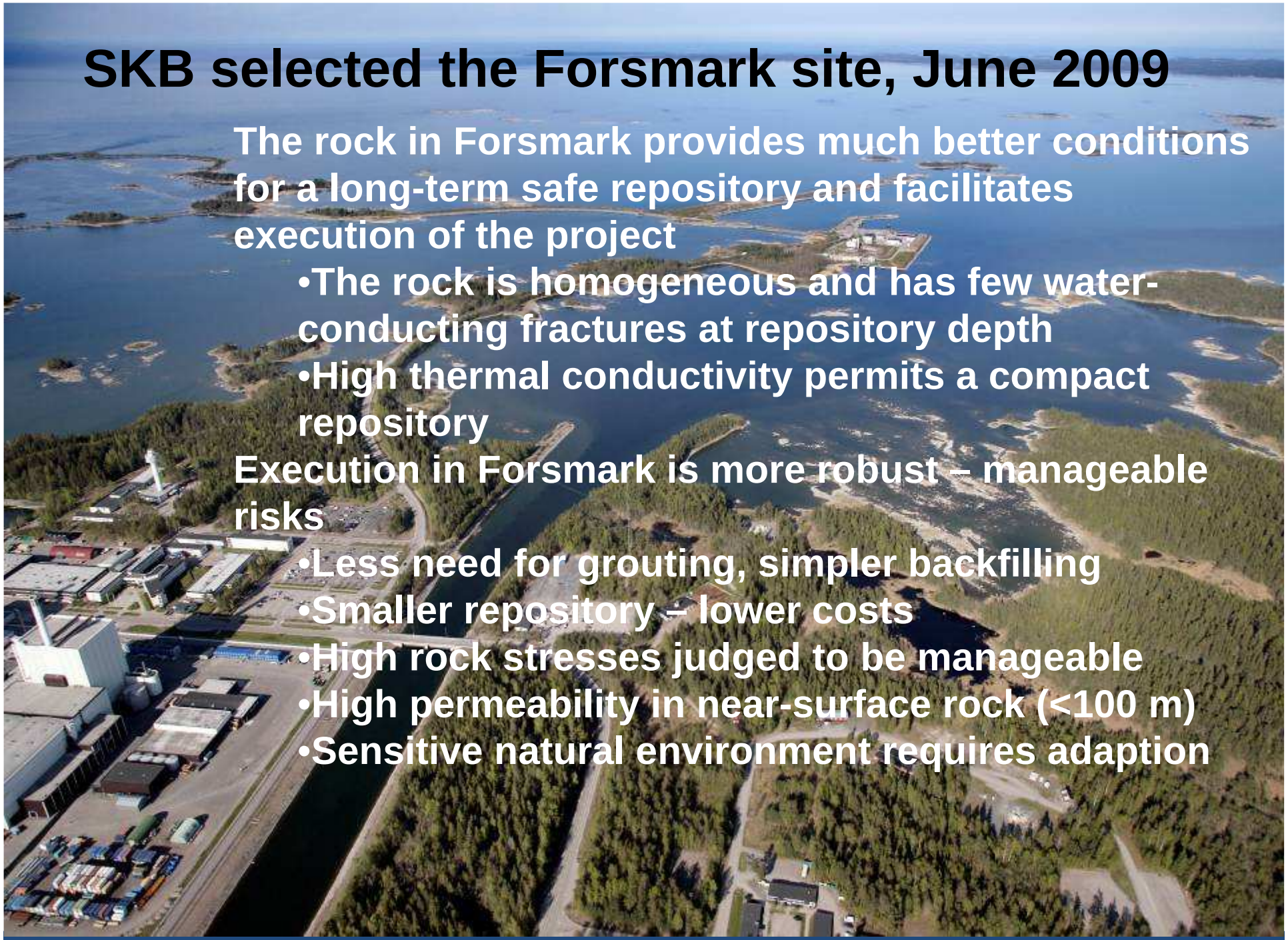
Societal resources

- Suppliers, human resources
- Public and private services
- Communications

Health and environment

- Occupational health and radiation protection
- Natural environment
- Cultural environment
- Residential environment
- Management of natural resources

SKB selected the Forsmark site, June 2009



The rock in Forsmark provides much better conditions for a long-term safe repository and facilitates execution of the project

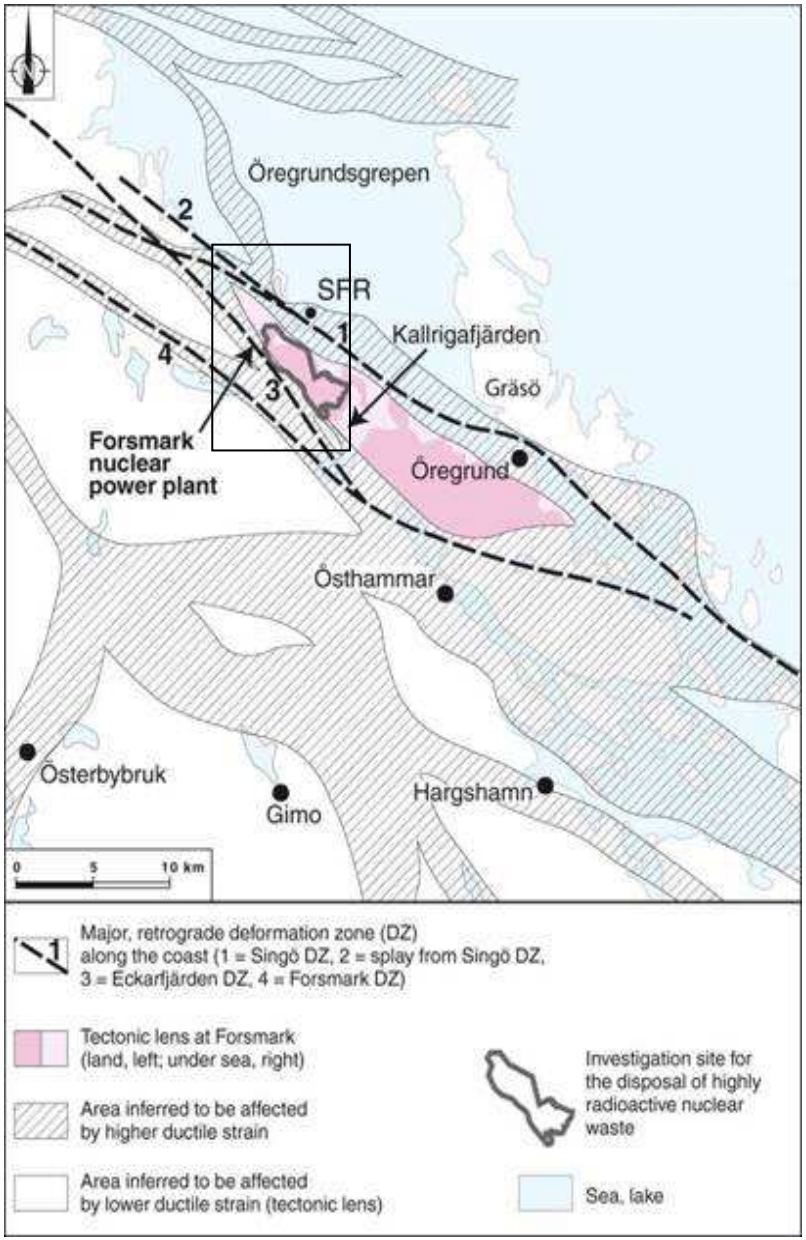
- The rock is homogeneous and has few water-conducting fractures at repository depth
- High thermal conductivity permits a compact repository

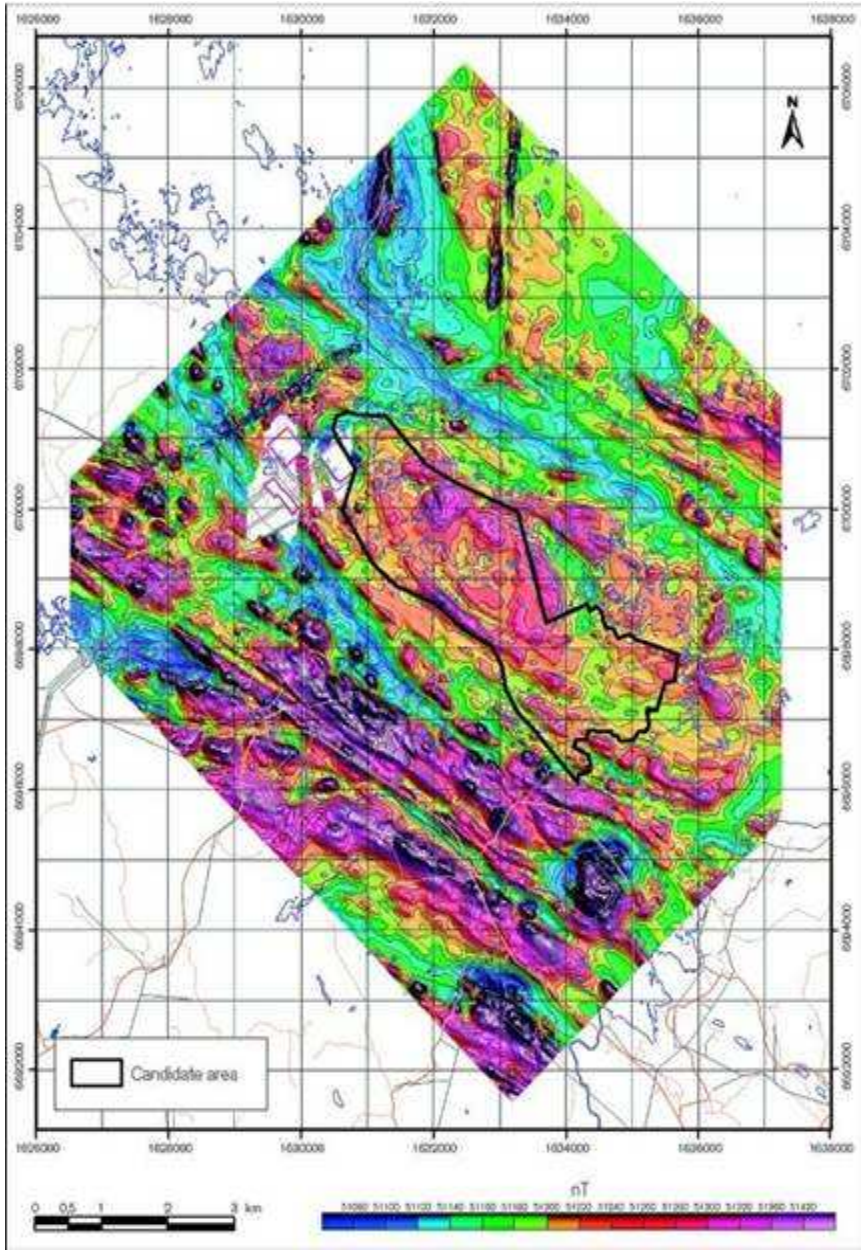
Execution in Forsmark is more robust – manageable risks

- Less need for grouting, simpler backfilling
- Smaller repository – lower costs
- High rock stresses judged to be manageable
- High permeability in near-surface rock (<100 m)
- Sensitive natural environment requires adaption

Location of the Forsmark site, Sweden

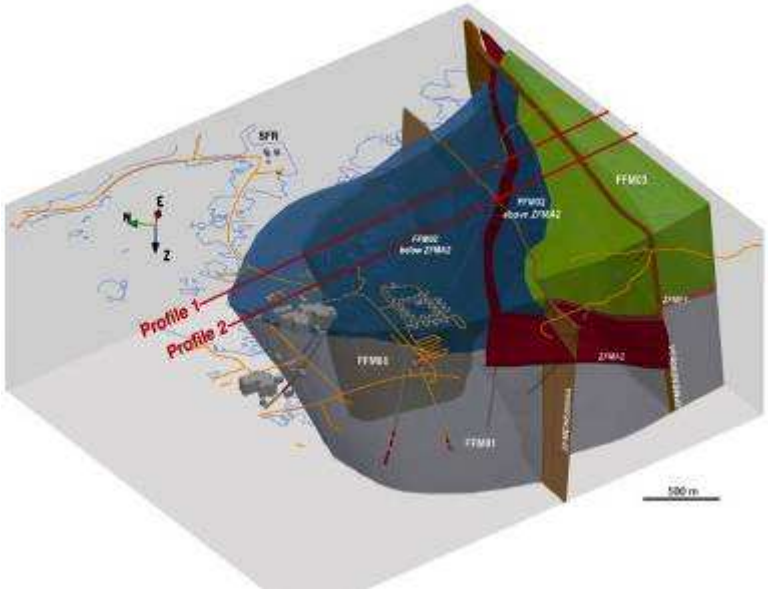
The tectonic lens at Forsmark



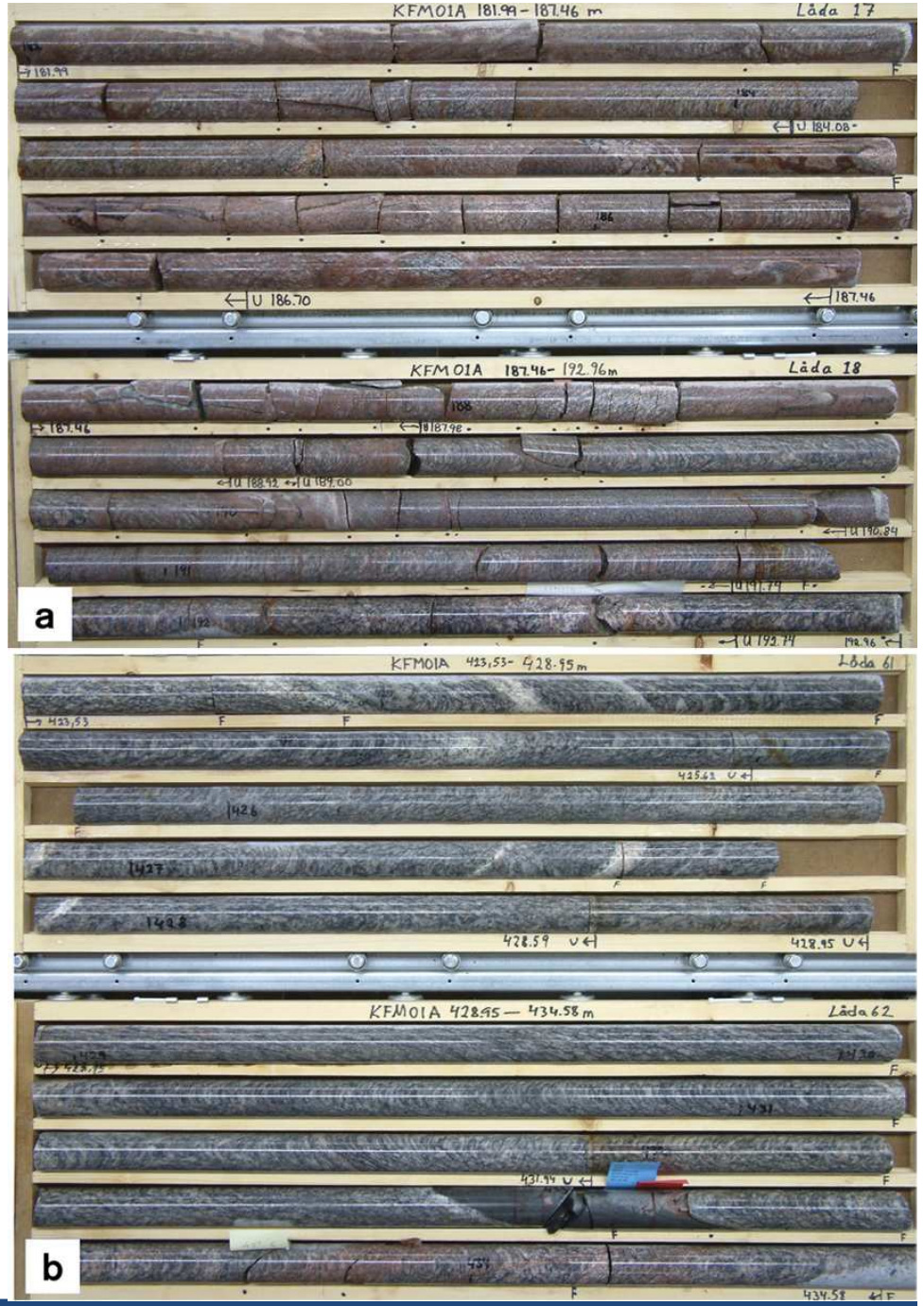


Fracture domains

Fracture domain FFM02.
Hematite staining and high frequency of open fractures.



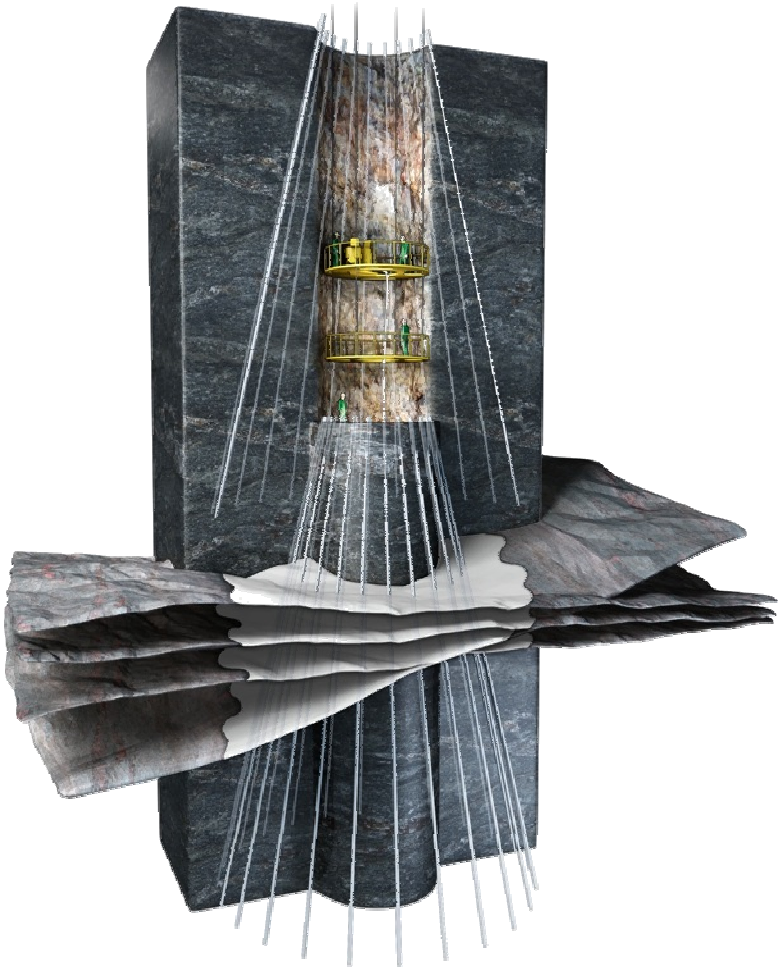
Fracture domain FFM01.
Lack of open fractures.



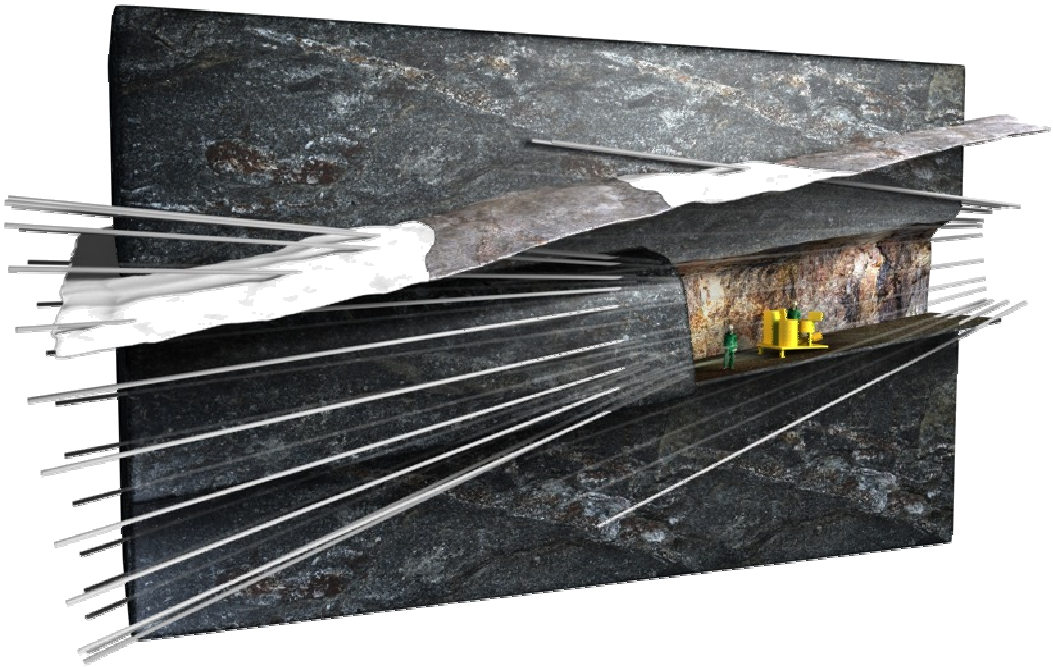
Characteristics of shallow open fractures

Infilled with soil or Very large water capacity

Need for grouting

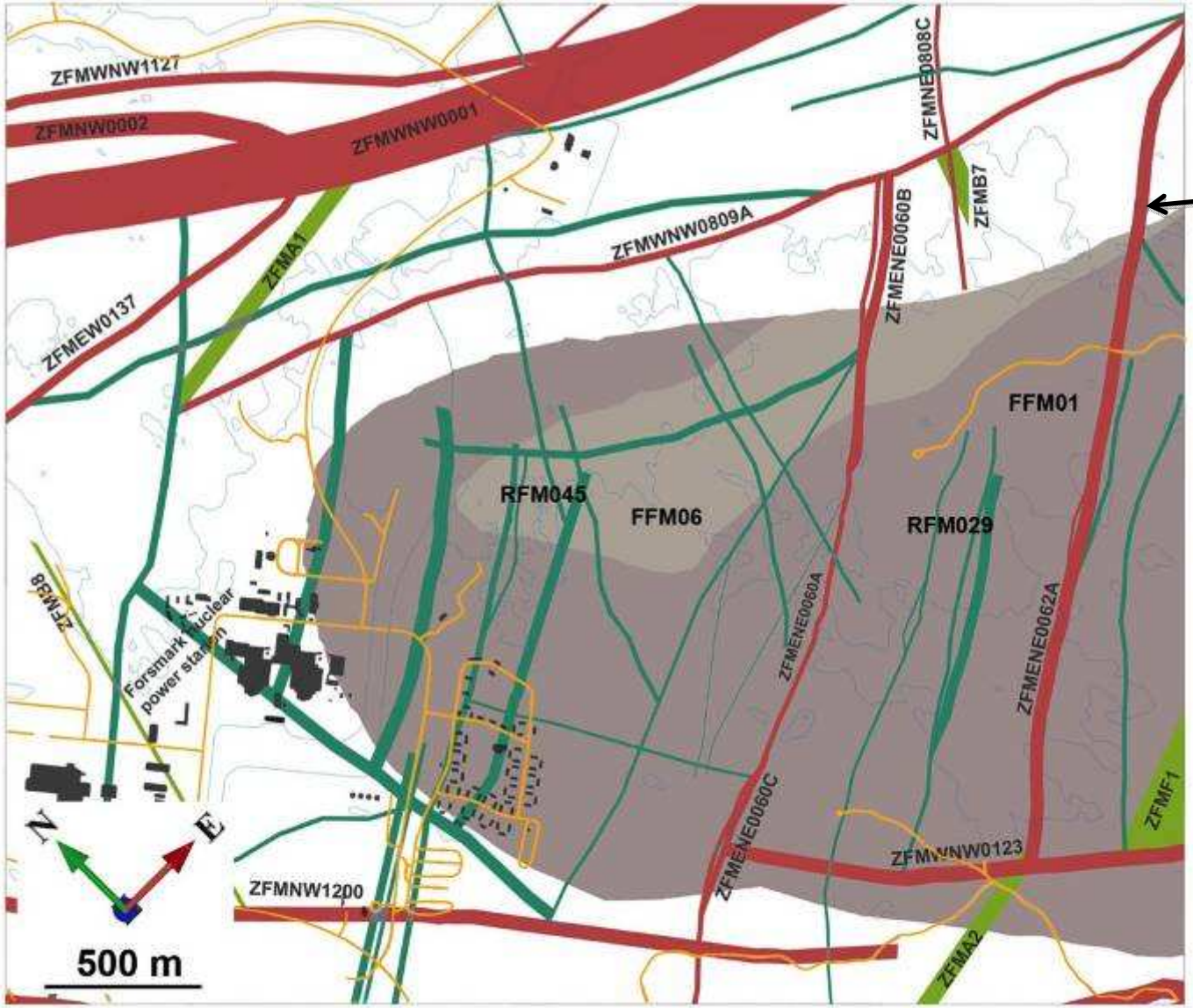


Shaft Sinking



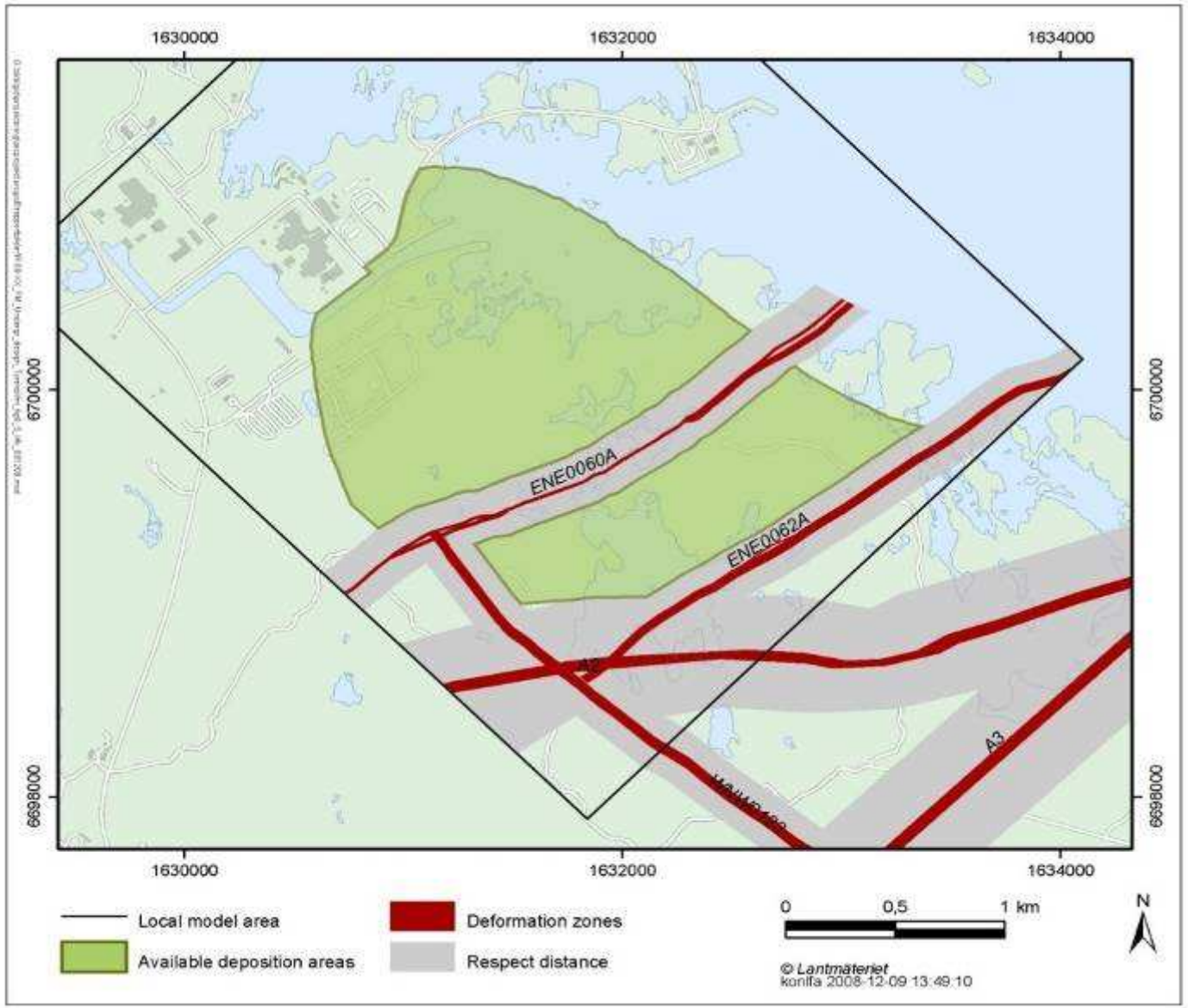
Ramp advance

Fitting the Deposition Tunnels to Geology



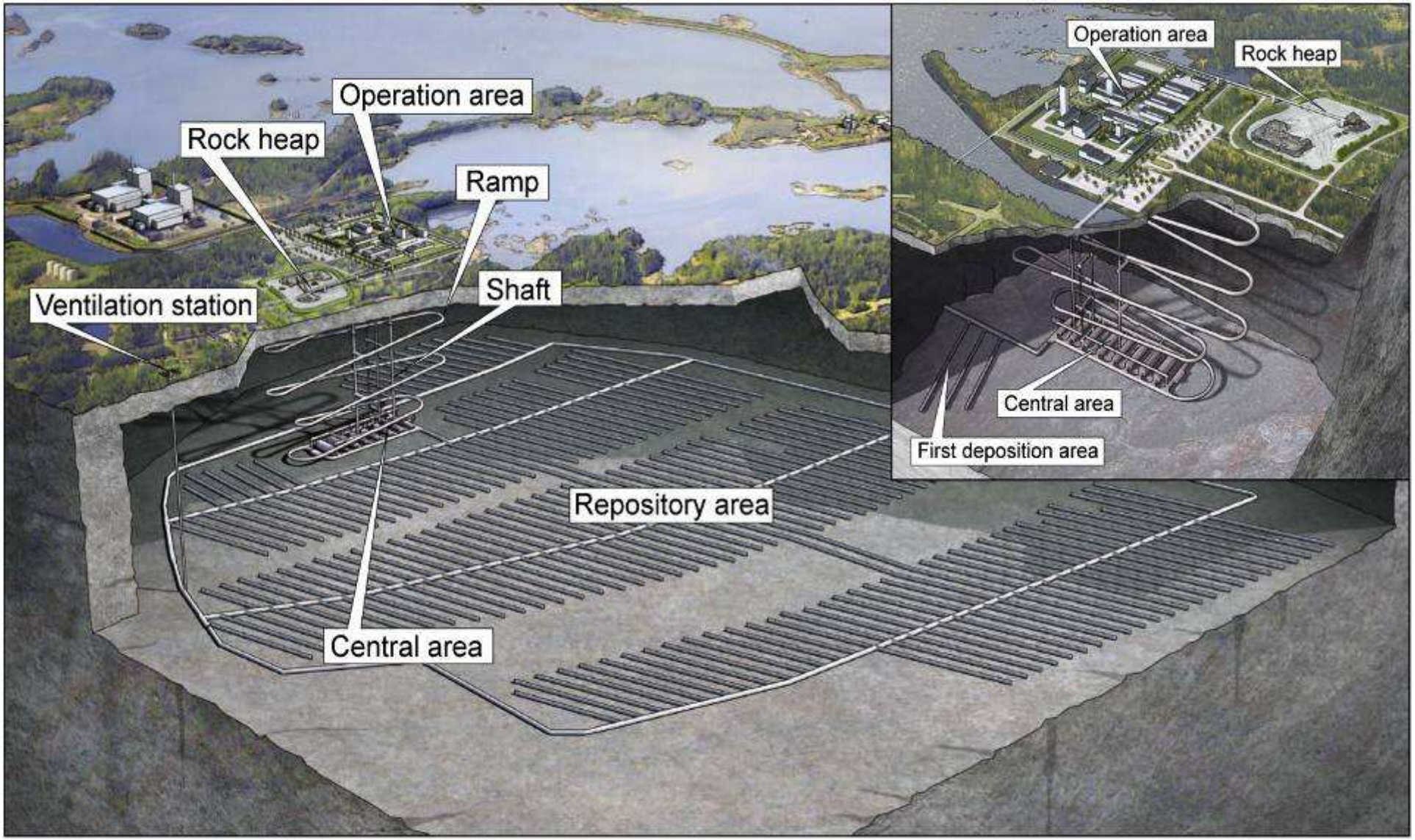
Deformation Zones

Respect distance from Deformation Zones

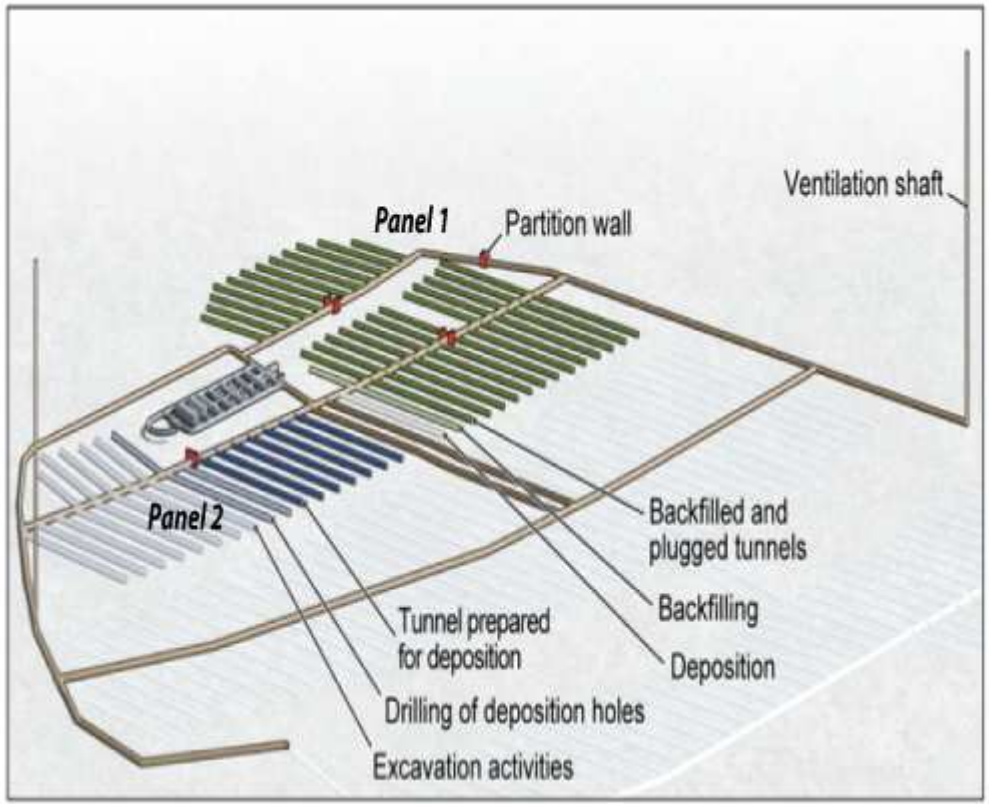


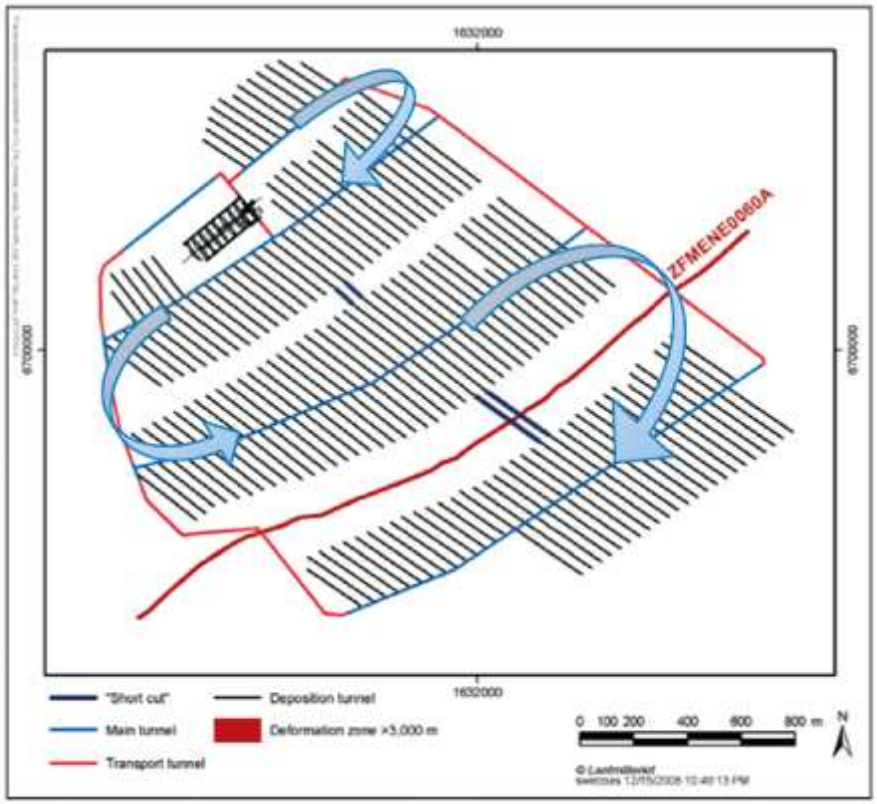
Deposition tunnels must keep 100 m from Deformation Zones longer than 3 km

Repository layout



Repository Development





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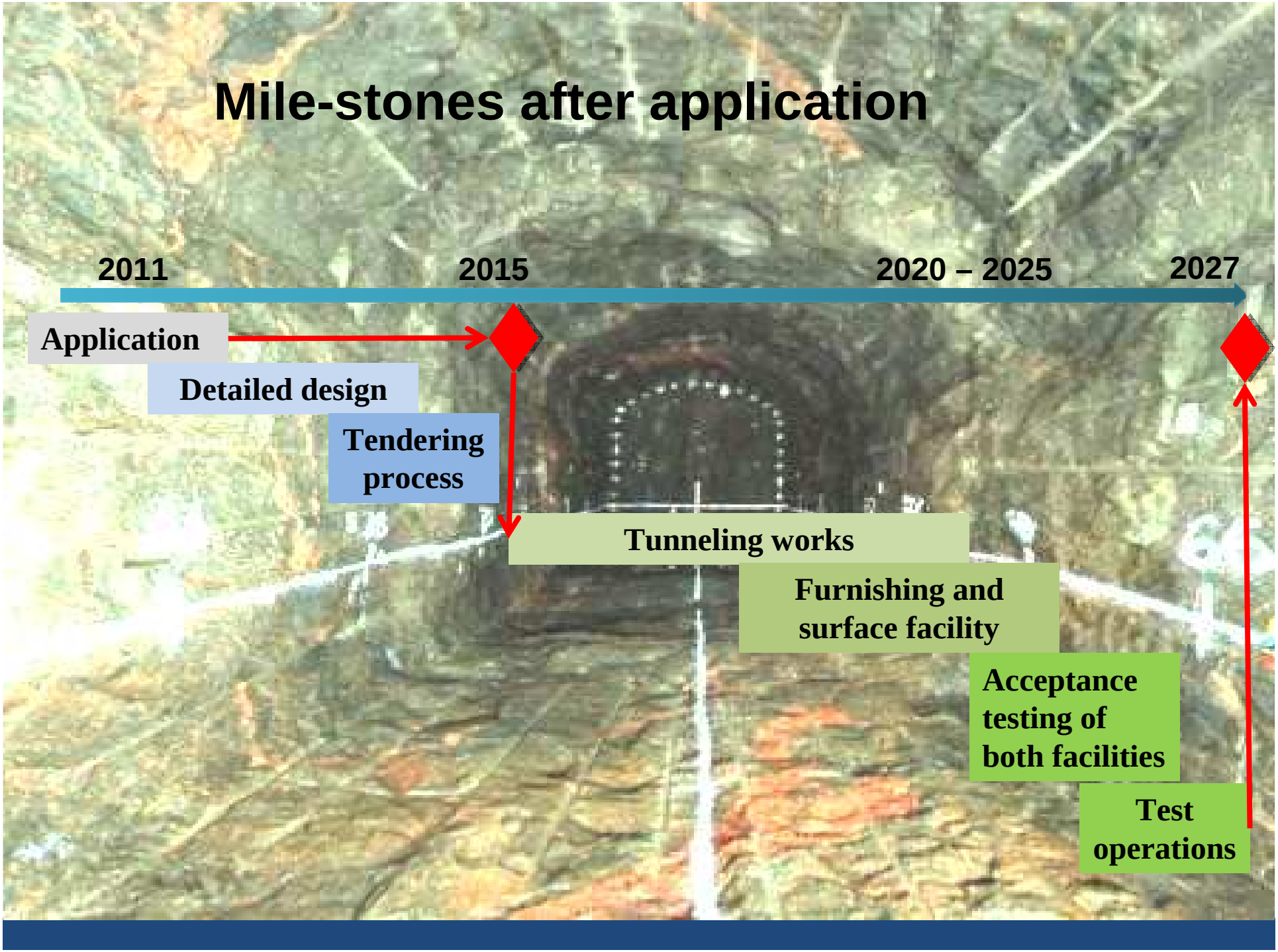

Mile-stones after application
2011
2015
2020 – 2025
2027
Application
Detailed design
Tendering process
Tunneling works
Furnishing and surface facility
Acceptance testing of both facilities
Test operations

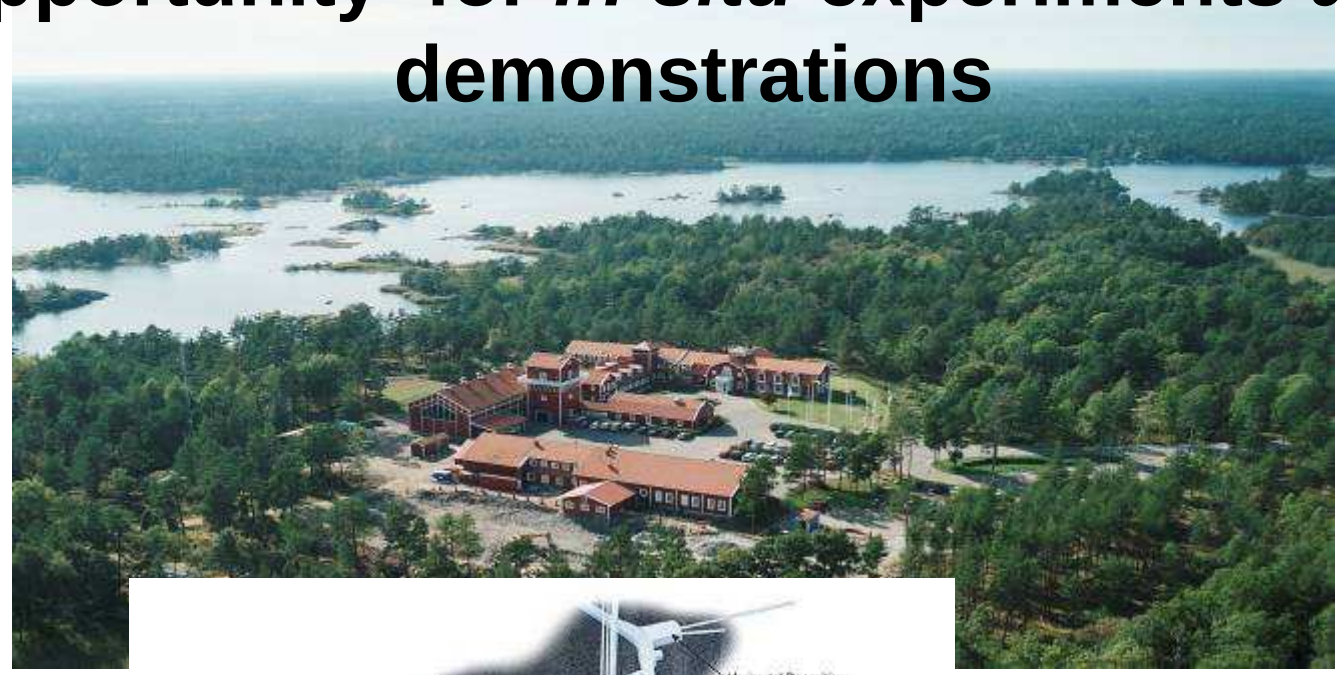
Need of Technical Development for the Repository at the Forsmark Site

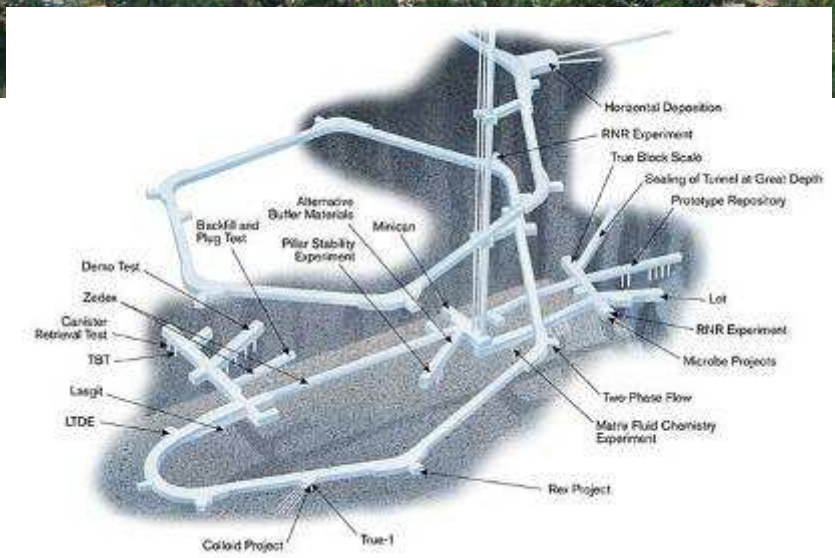
- Management of tentative large in-ruch of water in the upper part of the accesses.
  - –Grouting, accepted grouting materials
- Strategies to control possible highly stressed ground at depth
- Confirm capacity to meet demands of efficiency in construction works AND controlling the extent of the EDZ
- Mantain the required buffer density if spalling would be extensive in deposition holes

Verify process understanding and design constrains under controlled conditions

- Conditions that influence on rock strength
- Sealing of small aperture fractures at large depth (high pressure)
- Excavation methods to minimaze the Excavation Damage Zone (EDZ)
- Rock support measures that minimaze the use of concrete
- Experience on degradation of unsupported tunnels in crystalline rock

The Äspö HRL provides an unique opportunity for *in-situ* experiments and demonstrations





Concluding remarks

- A strategy for design was developed in conjunction to the planning of the Site Investigation
- Design was carried out at two sites, providing
  - Site specific layouts for the PA/SA studies
  - Input to the site selection on Constructability and Environment Impact Assessments for the two sites
- SKB did Site Selection in June, 2009, and submitted the Application for a Final Repository for Spent Fuel at the Forsmark Site to the Gorvernment in March, 2011.
- Äspö HRL has provided, and will continue to provide unique oppertunities to improve rock engineering methods to meet the specific requirements for a Nuclear Repository, as well as geoscientific research

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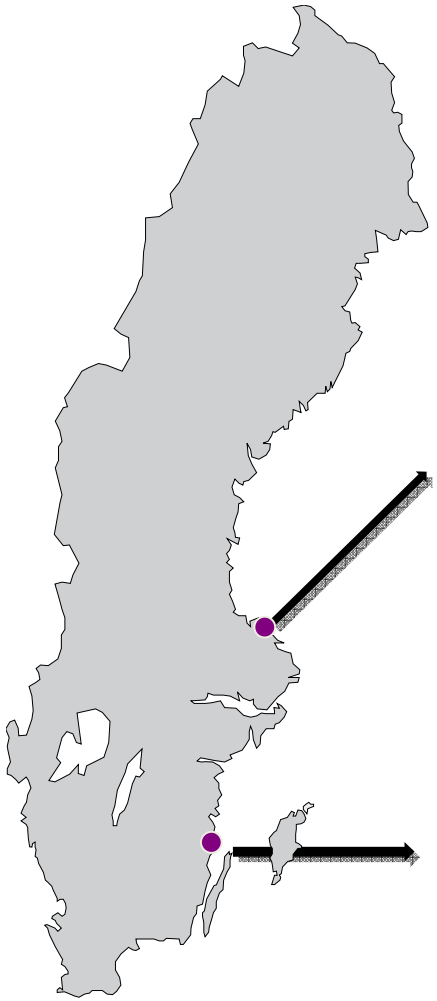
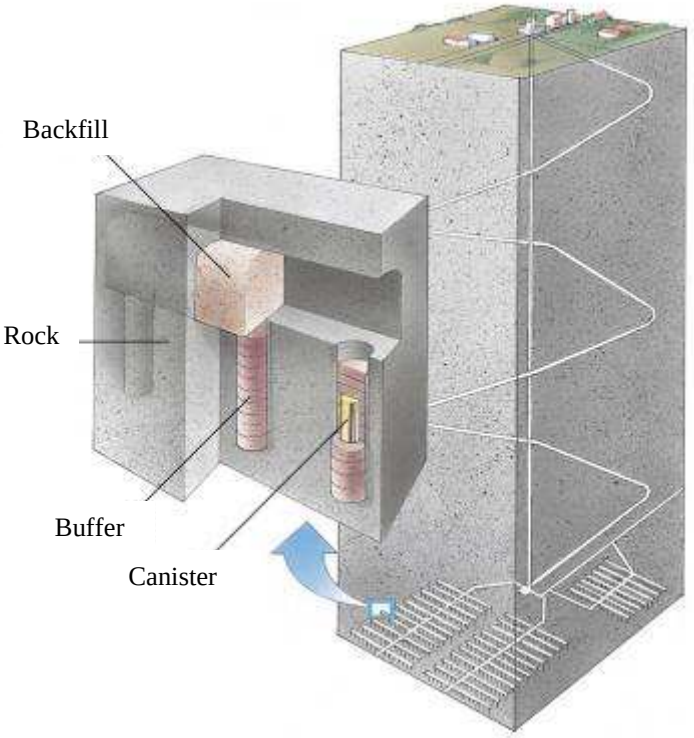
7. **Application process**

Facilities applied for March 2011



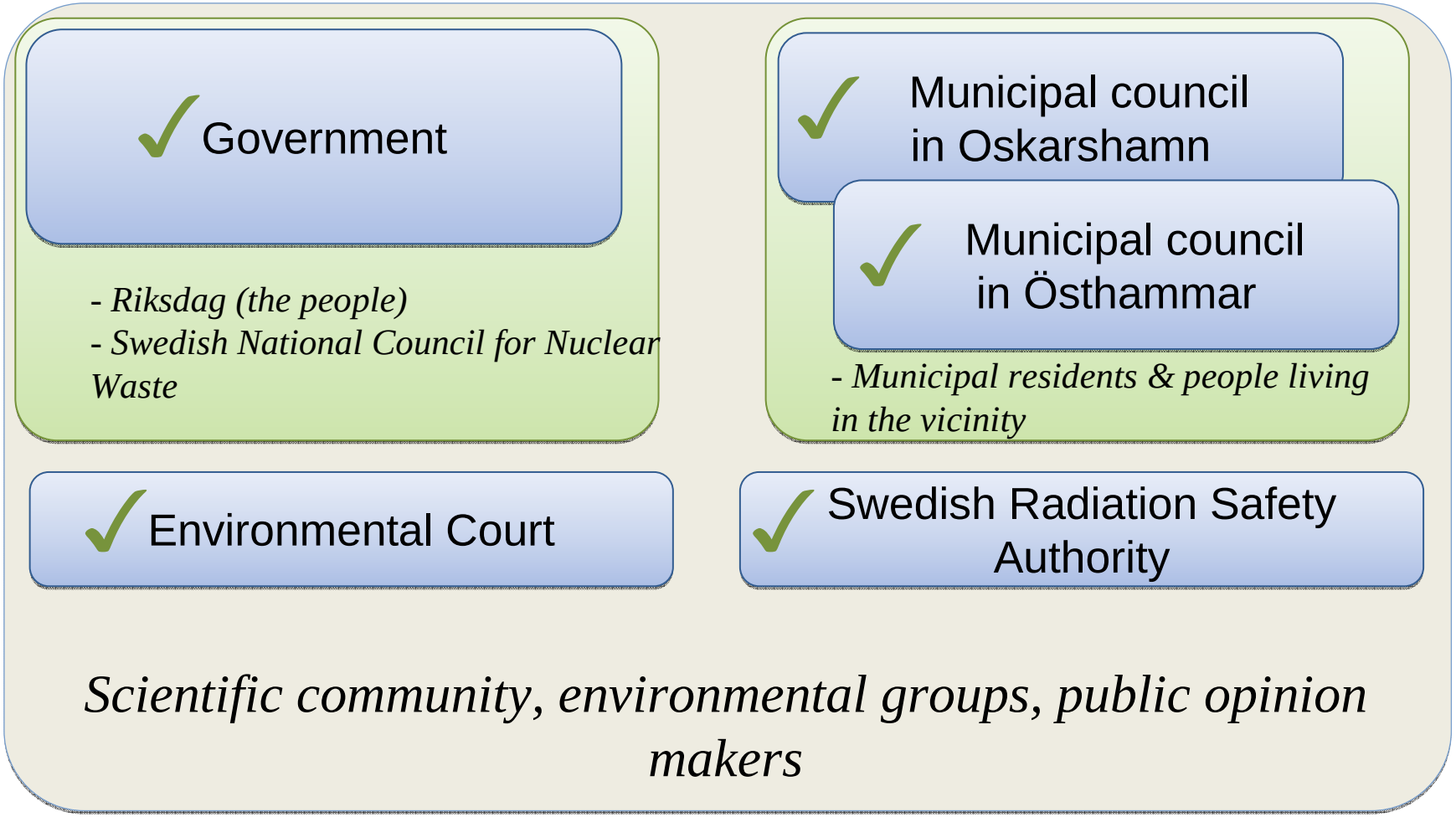
Spent Fuel Repository at Forsmark

Encapsulation plant in Oskarshamn



The legal framework

- Two laws
  - –The Environmental Code
  - –The Nuclear Activities Act
- Two nuclear facilities at two different sites
- Two different Environmental courts

- Evaluation of if the proposed facilities and activities meet the stated aims and are in accordance with legal requirements

SKB needs five 'yes'