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Horonobe Underground Research Laboratory Project
Plan of the Investigation Program
for the 2004 Fiscal Year (2004/2005)

April, 2004

Japan Nuclear Cycle Development Institute
Horonobe Underground Research Center

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Horonobe Underground Research Laboratory Project Planned Investigation Program for the 2004 Fiscal Year (2004/2005)

(Translated Document[1])

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Abstract

The Horonobe Underground Research Laboratory Project is planned to extend over 20 years. Investigations will be conducted in three phases, namely from the surface (Phase 1), during construction of the underground facility (Phase 2) and in the underground facility itself (Phase 3). The 2004 fiscal year is the fifth year of the Phase 1 surface-based investigations.

Geophysical, geological, surface hydrogeological and borehole investigations are being carried out in order to develop techniques for exploring the geological environment. Geoscientific models are being constructed, revised and verified based on the acquired data. As part of the development of techniques for monitoring the geological environment, long-term monitoring of groundwater pressures is ongoing in a borehole equipped in a previous investigation phase. Long-term monitoring systems are also being installed in the remaining boreholes at the site and measurements are ongoing. Development of a remotely operated monitoring system (ACROSS) is also continuing. Studies on the long-term stability of the geological environment include monitoring with seismographs, GPS and electromagnetic surveys. With a view to developing engineering techniques for application in the deep underground environment, a detail design for the underground facility has been defined.

To provide input for the detailed planning of the Phase 2 and 3 investigations, laboratory tests are being carried out on the transportation and emplacement of the engineered barriers and on tunnel reinforcement materials. With a view to improving their reliability, the appropriateness of safety assessment methods is being examined using field and laboratory data.

The design of the surface facilities has been defined and construction work has begun. Environmental monitoring is ongoing, as is collaboration with domestic and overseas research institutes.

* Horonobe Underground Research Center Coordination Group

1 This document is an English translation of Technical Document JNC TN5400 2003-003.

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幌延深地層研究計画　平成16年度調査研究計画

(翻訳資料[2])

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要旨

幌延深地層研究計画は、調査研究の開始から終了まで20年程度の研究であり、「地上からの調査研究段階（第1段階)」、「坑道掘削（地下施設建設）時の調査研究段階（第2段階)」、「地下施設での調査研究段階（第3段階)」の3つの段階に分けて実施する。平成16年度は、地上からの調査研究段階（第1段階）の5年目にあたる。

地質環境調査技術の開発では、物理探査、地質調査、表層水理調査、試錐調査を実施し、地質環境モデルの構築・更新および解析を行う。地質環境モニタリング技術開発では、既存の試錐孔における水圧観測を継続するとともに、試錐孔に長期モニタリング機器を設置し、水圧の観測を行う。また、遠隔監視システム(ACROSS)の開発を継続する。地質環境の長期安定性に関する研究では、地震計、GPSおよび電磁探査機器による観測を実施する。深地層における工学的技術の基礎の開発では、地下施設の実施設計を行う。

地層処分研究開発では、第2段階以降の試験計画を具体化するために、搬送定置装置や覆工材料に関する室内試験、および人工バリアの試設計を実施する。安全評価手法の高度化では、これまでの調査で取得したデータに基づき安全評価手法の適用性に関する検討を行う。

地上部の施設建設に関しては、地上施設の設計を行い、地下施設建設用地の造成を開始する。環境調査では、モニタリング調査を継続する。国内・海外の研究機関との連携も継続・発展させる。

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[2] 本資料は核燃料サイクル技術資料「JNC TN5400 2003-003 幌延深地層研究計画 平成16年度調査研究計画」を英訳したものである。

CONTENTS

1. Introduction

As part of the research and development program on geological disposal of high-level radioactive waste (HLW), the Horonobe Underground Research Center, a division of the Japan Nuclear Cycle Development Institute (JNC), is implementing the Horonobe Underground Research Laboratory Project (Horonobe URL project).

The Horonobe URL, where it is aimed to study the deep geological environment in sedimentary rock, is one of the underground research laboratories mentioned in the "Long-term Program on Research, Development and Utilization of Nuclear Energy (LTP)" published by the Atomic Energy Commission of Japan (AEC, 1994). The importance of the underground research laboratories is also stressed in the revised LTP published in 2000 (AEC, 2000). These facilities provide location for research and development on geological disposal technologies and on establishing reliable methodologies for safety assessment; they also play an important public relations role as destinations for visitors wishing to learn about geological disposal.

The role of JNC, as defined in the document "Securing Basic Technology for Atomic Energy" (Atomic Energy Subcommittee of the Energy Resources Research Committee, 2001), states that JNC should promote research and development (i.e. scientific study of the deep geological environment, improving the reliability on the geological disposal technologies and refinement of safety assessment methods) through acquisition of actual field data and associated modeling studies. This R&D work is to be conducted using the planned underground research facilities and laboratory-based test facilities such as the Geological Disposal Radiochemical Research Facility. The R&D areas mentioned above as being part of JNC's responsibility - scientific studies of the deep geological environment, improving the reliability of geological disposal technologies and refining safety assessment methods - correspond to the areas "Geoscientific Research" and "Research and Development on Geological Disposal" which from part of the Horonobe URL project.

The Horonobe URL project is planned to extend over a period of 20 years. The investigations are to be conducted in three phases, namely from the surface (Phase 1), during construction of the underground facility (Phase 2) and in the facility itself (Phase 3). This report summarizes the investigation program for the 2004 fiscal year (2004/2005), the fifth year of the Phase 1 investigations.

2. Outline of investigation program in 2004/2005

The investigations in 2004/2005 are focused on the Hokushin area, which was selected as the area for laboratory construction in July 2002. The main investigation region extends over about 9 km^2. Geophysical, geological, surface hydrogeological, and borehole investigations are being carried out to acquire the geoscientific data needed to develop techniques for investigating the geological environment. Together with previously existing data, the data acquired in this phase are used to construct and refine models of the geological environment. As part of the program for developing monitoring techniques for the geological environment, groundwater pressures have been observed using a long-term monitoring system in a borehole since the last fiscal year; it is now planned to install such systems in the remaining boreholes at the site. Design studies for the underground facility have been initiated to provide a basis for developing engineering techniques for the deep underground environment. The infrastructure for borehole and surface seismographs, GPS[3] (Global Positioning System) and electromagnetic surveys[4] was installed in 2002 and 2003 and work has begun in these areas.

Laboratory tests on swelling of buffer material using Horonobe groundwater and low alkalinity concrete materials are being carried out to provide input for planning the R&D work in Phases 2 and 3. Important geoscientific data and phenomena that should be considered in the safety assessment, and the required volume and accuracy of these data, are also identified.

Development of the construction site has started. Work on a research and development center and a core warehouse/workshop building[5] are underway and public relations facilities have been designed. Detailed plans for all the surface facilities are available. Monitoring of environmental parameters identified from investigations conducted in 2003 is ongoing.

Collaboration with experts from domestic and overseas research institutes continues to form an important part of the program.

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[3] GPS, developed in the USA, is a satellite navigation system used for determining one's precise location and providing a highly accurate time reference almost anywhere on Earth or in Earth orbit. It uses an intermediate circular orbit (ICO) satellite constellation of at least 24 satellites.

[4] The primary electromagnetic field, originating in the sunspot activity, generates the secondary electromagnetic field on reaching the earth. The electromagnetic survey method is used to investigate sub-surface geologic structure.

[5] Building for storage of drillcores and storage and maintenance of investigation equipments.

3. Geoscientific research

3.1. Development of techniques to investigate the geological environment

3.1.1. Acquisition of geoscientific data

In 2004/2005, surface-based geophysical surveys, geological investigations and borehole investigations are being carried out to acquire data on geological structure, stratigraphy, hydraulic properties, groundwater chemistry, and rock mechanical properties. Observation of river flow using water flux meter and sampling and chemical analyses of river water, as well as acquisition of meteorological data using weather surveying equipment, continue to form part of the surface hydrogeological investigation program. Applications for permits to carry out geophysical surveys, geological investigations and borehole investigations in 2005/2006 will be made in due course. Details are described in the following sections.

(1) Geophysical investigations

In the laboratory construction area and its surroundings, high-density reflection seismic surveys[6], multi-offset VSP (Vertical Seismic Profiling) surveys[7] and gravity surveys are being performed to obtain an understanding of key geological structures such as the Omagari Fault. The location and geometry of the Omagari Fault and other geological structures are derived by integrating such data with those from previous surveys.

(2) Geological investigations

In order to clarify parameters such as stratigraphic distribution and occurrence of faults, geographical feature are analyzed using satellite images, investigation of the rock sample from outcrop and gas occurrences in shallow boreholes. Laboratory studies include petrological/mineralogical and microfossile analyses.

(3) Surface hydrological investigations

Collection of meteorological data, including precipitation, temperature, humidity, wind velocity and direction, evapotranspiration rate is, continuing. These relevant equipments were installed in the laboratory construction area and its periphery by 2003. In order to determine the distribution and flow of near-surface groundwater, water level meters and a soil moisture meters have been installed in both existing and newly excavated boreholes. From the results of these observations, and chemistry of river water and precipitation, movement of water in the shallow underground environment can be understood.

To improve the resolution of observation in the laboratory construction area and its vicinity, river flux meters has been relocated and a meteorological observation system has been installed.

(4) Borehole investigations

Two vertical boreholes with depths of approximately 500 m and one with a depth of 1000 m have been drilled. These boreholes are used to monitor groundwater pressure and chemistry before, during and

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[6] In 2002, reflection seismic surveys were performed with 25-meter intervals between survey points in order to determine geological features and structures over a wider area. In 2004, surveys with smaller intervals of several meters looked at the geological structure of Omagari Fault and its periphery in more detail.

[7] Multi-offset VSP survey have a transmitter on the surface and a receiver in a borehole. Geological formations are investigated by carrying out measurements between borehole and ground surface. "Multi-offset" indicates that the transmitter is moved over distances of a few dozen meters in order to build up a 3D image of underground structures.

after the construction of the underground facility. Investigation in the 1000 m deep borehole will be carried out in FY 2004/2005. The program includes the following:

a) Drillcore investigations

- Geological characterization: core description (lithology, fractures, etc.), petrographical/mineralogical investigations, chemical analysis, age dating and microfossil analyses.
- Rock mechanical properties: physical property tests (porosity, density, resistivity, seismic wave velocity, etc.) and mechanical tests (uniaxial and triaxial compressive strength, tensile strength, etc.).
- Hydraulic properties: hydraulic conductivity tests in the laboratory.
- Groundwater chemistry: porewater extraction and chemical analysis.

b) Borehole investigations

- Rock mechanical properties: geophysical logging (resistivity, density, neutron, temperature, sonic, caliper, etc.), stress measurements.
- Groundwater chemistry: groundwater sampling and comprehensive chemical analyses (major component, isotope, gas, and microbes).
- Hydraulic tests for understanding hydraulic properties and head distribution.

3.1.2. Modeling the geological environment and predicting changes caused by construction of the underground facility

Geological, hydrogeological, hydrochemical and rock mechanical models have been constructed and refined, based on data acquired up to 2003. Changes in rock properties, groundwater flow and groundwater chemistry caused by the construction of the underground facilities are predicted using these models. All data are stored and managed in a comprehensive database system.

(1) Geological model

The geological model dating from 2001-2003, which described the distribution of sedimentary formations, faults and folds, will be verified using new data from geophysical surveys, geological investigations and borehole investigations carried out in 2004/2005.

(2) Hydrogeological model

A hydrogeological model of the laboratory construction area and its periphery was constructed based on existing models and data from the borehole investigations in 2003/2004. The volume of inflow and changes in groundwater pressure caused by construction of the underground facility are predicted using this model. Flow of groundwater with different densities (e.g. fresh and saline water) and with dissolved gas is also analyzed.

(3) Hydrochemical model

Evolution of groundwater chemistry is interpreted from chemical analyses of groundwater samples pumped from boreholes and porewater samples, as well as from mineralogical and chemical analysis of core samples. The existing model is then revised to describe the spatial distribution of chemical properties.

(4) Rock mechanical model

The rock mechanical model, which describes the distribution of rock strength and stress parameters, is revised based on data from laboratory tests of core samples and measurements in boreholes; these data was obtained in 2003/2004. The model is used to evaluate the stability of rock caverns. Changes in rock mechanical properties caused by the construction of underground facility are predicted using this model.

3.1.3. Development of investigation techniques and equipment

Drilling techniques which can control the angle and direction of boreholes are being developed. The applicability of geophysical and analytical techniques in boreholes and at ground surface is also being examined. The suitability of equipment used to measure pH and Eh and the composition and volume of dissolved gas is being examined for measurements to be conducted under the pressure and temperature conditions prevailing in deep boreholes.

3.2. Development of techniques for long-term monitoring of the geological environment

3.2.1. Development of monitoring techniques in boreholes

Groundwater pressure and chemistry are measured continuously before, during and after the construction of the underground facility to determine the influences of construction and investigation activities. In 2004/2005, monitoring will continue in a borehole equipped in a previous investigation phase and relevant equipment is also being installed in the remaining boreholes at the site. Methods for real-time description and evaluation of results are also being examined.

3.2.2. Development of remotely operated monitoring system

The Accurately Controlled Routinely Operated Signal System (ACROSS), a monitoring system using seismic and electromagnetic waves, will be used to observe changes in the geological environment before, during and after the construction of the underground facility. Test observations started in 2004/2005.

3.3. Development of engineering techniques for the deep underground environment

The detailed design of the underground facility will be finalized in 2004/2005. As well as providing appropriate locations for the geoscientific investigations, the intention that the facility should provide an opportunity for the public to experience the deep underground environment also has to be taken into consideration. Safety thus has the highest priority and evaluation of cavern stability and measures for preventing/managing hazards such as tunnel fire are considered in detail in the design studies.

3.4. Study on the long-term stability of the geological environment

3.4.1. Seismological studies

Seismographs were installed at the ground surface and at the bottom of a 141 m deep borehole in 2002-2003. These make up a monitoring system for detecting micro-earthquakes in the Horonobe region. Monitoring is underway and the hypocenter distribution is being analyzed; the results are being integrated with data from existing seismograph systems set up by other research institutes and universities.

3.4.2. Diastrophic study

A survey is being carried out to obtain information on topographical changes, deformation processes and the weathering of geological formations. The tectonic history and climate changes in the Horonobe area are also being investigated. These data are integrated with existing information to provide a comprehensive documentation of tectonic evolution and climate changes in the Horonobe area from the Neogene to Quaternary.

The amount of crustal movement and changes in electromagnetic properties in deep underground are analyzed by GPS and electromagnetic measurements. These observations are performed continuously.

4. Research and development on geological disposal technology

4.1. Improving the reliability of disposal techniques

4.1.1. Verification of engineered barrier technology

In Phases 2 and 3, investigations on the transportation and emplacement of the engineered barriers, rock support measures and backfilling of tunnels are foreseen. To make detailed plans for these investigations (e.g. objectives, test items, test layout, etc.), laboratory tests are being carried out on the degree of precision required for the transportation and emplacement equipment and on materials such as low-alkaline concrete.

Laboratory tests on over pack corrosion are also being carried out using Horonobe groundwater.

4.1.2. Confirmation of designing methods of engineered barrier

The long-term behavior of engineered barriers and the surrounding rock will be investigated in the Phases 2 and 3. In preparation for these investigations, preliminary designs for the engineered barrier system are being carried out. Data from swelling tests performed in the laboratory on buffer material using Horonobe groundwater and from surface-based investigations are used in the design.

4.2. Improving the reliability of safety assessment methods

Scenarios and models for safety assessment, and associated input parameters, are selected and simulations of groundwater flow and nuclide migration with associated uncertainty analysis[8] are carried out. Data from radionuclide migration tests on drillcore samples in the laboratory and from surface-based investigations are used for these studies. Based on the results, the geoscientific data and phenomena which are relevant to safety assessment and resultant requirements in terms of quantity and accuracy of data are identified.

[8] Uncertainty analysis:
In the safety assessments in geological disposal, uncertainties are inevitable because of the heterogeneity of natural geological structures and the long-term nature of the assessment (several tens of thousands of years and more). Therefore, assessments are carried out with consideration of possible data ranges or fluctuations in order to derive an evaluation of model output uncertainty. This is termed an "uncertainty analysis".

5. Surface facilities and environmental surveys

5.1. Surface facilities

Development of the construction site continued in 2003. Construction of research and administration offices, core storage buildings and a workshop is underway, and a public exhibition hall is being designed.

5.2. Environmental survey

The environmental parameters to be surveyed in the area around the construction site were reviewed in 2003-2004 and monitoring of new parameters (e.g. noise, vibration, water quality) is now ongoing.

6. Cooperation with other research institutes

Interaction with a wide range of experts from both domestic and overseas research establishments is an essential component of the Horonobe URL project because of the highly interdisciplinary nature of the research and development activities.

In addition to promoting the wider participation of research organizations in Japan and abroad, collaborative research will be conducted with the organizations listed below.

Partners of cooperative studies at present are:

- **Saitama University** for studies of groundwater flow modeling
- **Central Research Institute of Electric Power Industry (CRIEPI)** for studies of geological and groundwater characteristics (including development of controlled drilling techniques)
- **Shizuoka University** for analysis and quantitative evaluation of the structure and size of microbial populations using the gene mapping technology
- **Yamaguchi University** for measurements of the volume of in-situ methane using a dissolved methane sensor
- **Kyoto University** for studies of the Acoustic Emission (AE)[9] characteristics of soft sedimentary rock using drillcores and in-situ measurement techniques
- **Nagra**[10] (Switzerland) for development of hydrogeological borehole investigation techniques
- **SNL**[11] (USA) for development of uncertainty analysis methodologies.

In addition, research on a range of topics including sedimentary rock characteristics is being conducted together with **the Horonobe Research Institute for the Subsurface Environment**[12]**.**

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9 Acoustic emission monitoring is a non-destructive means geomechanical evaluation which passively measures sound waves generated naturally by stress within a rock mass.

10 Nationale Genossenschaft für die Lagerung radioaktiver Abfälle (National Cooperative for the Disposal of Radioactive Waste). Nagra is responsible for geological disposal research in Switzerland. Part of its program includes in-situ investigations in domestic underground rock laboratories (e.g. Grimsel).

11 Sandia National Laboratories. SNL is under the US Department of Energy and has carried out numerous investigations as part of the WIPP (Waste Isolation Pilot Plant) and Yucca Mountain Project.

12 "H-RISE" for short. This is a research institute under the Northern Advancement Center for Science and Technology (NOASTEC) established in 2003 in Horonobe. Scientific research on utilization of underground space is planned.

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APPENDIX

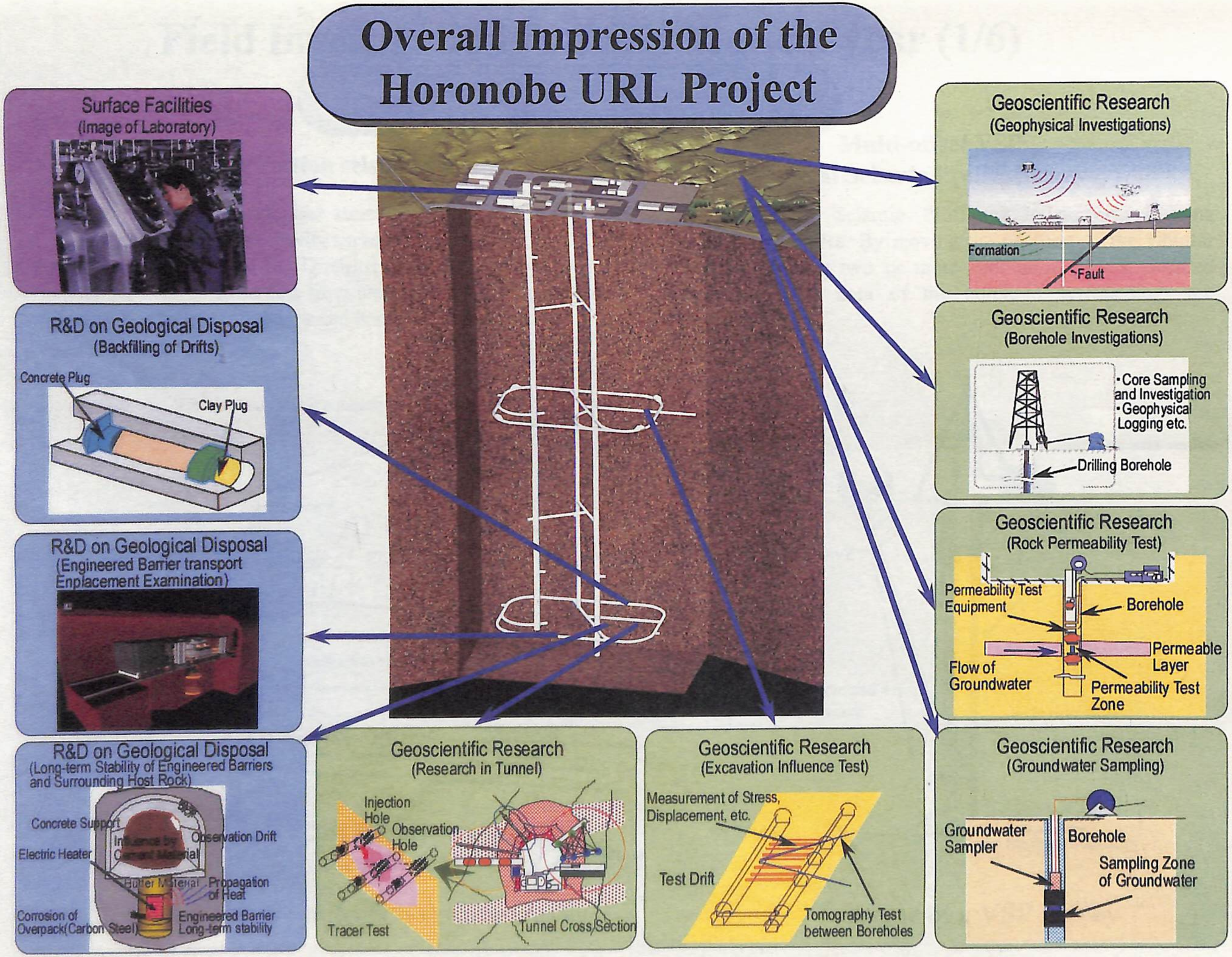
Overview of the surface-based investigations (Phase 1)

Items	Content	Objectives	Application of results	2000FY (H12) – 2005FY (H17): Surface-based investigations (Phase 1); area selection; (Phase 2). Selection of area for URL construction / Investigations in/around the selected area
Geoscientific Research				
1. Development of investigation techniques for the geological environment				
1.1 Acquisition of geoscientific data				
(1) Airborne survey	Heli-borne survey (magnetics, electromagnetics, natural gamma).	To determine geology and geological structures to a depth of 150 m.	Geological modeling. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area.	
(2) Surface geophysics	Electromagnetics.	To investigate geology to 2000 m depth. To obtain detailed information on geological formations and structures in the borehole vicinity in the selected area.	Geological modeling. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design.	regional; detailed
	Reflection seismics.	To obtain detailed information on geological formations and structures to 2000 m depth in the selected area.	Geological modeling. Planning and interpretation of investigations. Arrangement of boreholes. Construction design.	
	VSP surveys.	To investigate in detail geological formations and structures in the borehole vicinity in the selected area.	Geological modeling. Planning and interpretation of investigations. Arrangement of boreholes. Construction design.	HDB-1, 3, 4, 5; HDB-6
(3) Surface geology	Lineament interpretation and geological mapping.	To estimate the distribution of geological structures. To confirm stratigraphy.	Geological modeling. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design.	lineament mapping; mapping; mapping; mapping
	Laboratory tests (petrology, mineralogy, geochemistry, geochronology, microfossils).	To characterize rock formations and confirm stratigraphy.	Geological, hydrochemical and solute transport models. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design.	
(4) Surface hydrogeology	Meteorological monitoring (precipitation, temperature, humidity, sun exposure, evaporation), river flux, water table (wells, springs).	To estimate recharge rates.	Hydrogeological modeling. Planning and interpretation of investigations. Arrangement of boreholes.	preparation (system, location); installation, monitoring
(5) Borehole investigations	Geophysical logging, hydraulic tests, groundwater/gas chemical analyses, stress measurements.	To acquire physical, hydraulic and hydrochemical properties.	Geological, hydrogeological, hydrochemical and rock mechanical models. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Constuction design.	HDB-1, 2 (700mx2) (for area selection); HDB-3, 4, 5 (500mx3) (in/around the selected area); HDB-6, 7, 8 (500mx3); HDB-9, 10, 11,12 (500mx3,1000m)
	Core mapping, laboratory tests (petrology, mineralogy, geochemistry, geochronology, microfossils, physical and rock mechanical properties, stress, hydraulic conductivity, porewater chemistry).	To characterize rock formations and confirm stratigraphy.	Geological, hydrogeological, hydrochemical, solute transport and rock mechanical models. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design.	
1.2 Modeling of the geological environment and prediction of changes caused by construction of the underground facility				
(1) Geological model	Construction/revision of the model.	To understand the spatial distribution of geological features. To provide input for hydrogeological/hydrochemical/rock mechanical models. To determine the degree of uncertainty with an increasing amount of data.	Hydrogeological, hydrochemical and rock mechanical models. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.	model construction/revision
(2) Hydrogeological model	Construction/revision of the model. Groundwater flow simulation. Planning of fresh/saline water boundary study.	To understand groundwater flow, head distribution. To determine the degree of uncertainty with an increasing amount of data.	Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.	selection of methods; model construction/revision, groundwater flow simulation
(3) Hydrochemical model	Construction/revision of the model.	To understand hydrochemical conditions and their evolution. To determine the degree of uncertainty with an increasing amount of data.	Validation of hydrogeological model. Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.	model construction/revision
(4) Rock mechanical model	Construction/revision of the model.	To understand the spatial distribution of rock mechanical conditions. To determine the degree of uncertainty with an increasing amount of data.	Planning and interpretation of investigations. Arrangement of boreholes. Selection of construction area. Construction design. Development of comprehensive investigation/modeling methodology.	model construction/revision
Prediction of changes related to construction	Predicting conditions of the geological environment and changes associated with underground facility construction.	To understand the conditions of the geological environment and changes caused by underground facility construction. To predict changes during/after construction.	Construction design. Development of comprehensive investigation/modeling methodology.	
Database construction	Digitizing and management of all data.	To store and apply data systematically and efficiently.	Planning and interpretation of investigations. Geological, hydrogeological, hydrochemical, rock mechanical and solute transport models. Construction design. Development of comprehensive investigation/modeling methodology.	
1.3 Development of investigatior niques and equipment				
Borehole drilling	Improvement and development of drilling techniques and equipment for soft sedimentary rock (drilling mud, casing).	To provide optimum conditions for core and borehole investigations and monitoring.	Core and borehole investigations and monitoring.	selection of techniques and equipment; improvement of equipment
Borehole investigations	Improvement and development of techniques and equipment for hydraulic testing and groundwater sampling in the presence of oil/gas.	To acquire reliable data for hydrogeological/hydrochemical investigations.	Hydrogeological and hydrochemical investigations.	selection of techniques and equipment; improvement of equipment

APPENDIX

Overview of the surface-based investigations (Phase 1)

Items	Content	Objectives	Application of results	2000FY (H12) – 2005FY (H17): Surface-based investigations (Phase 1) / (Phase 2); area selection; Selection of area for URL construction / Investigations in/around the selected area
2. Development of techniques for monitoring the geological environment				
2.1 Development of monitoring techniques in boreholes				
	Development and improvement of equipment. Installation of equipment and start of monitoring.	To acquire reliable data on initial conditions before construction and changes during/after construction.	Monitoring techniques and methodologies. Hydrogeological and hydrochemical models.	improvement of equipment; installation, monitoring
2.2 Development of remotely operated monitoring systems				
	Improvement of data transmission/detection system using seismic and electromagnetic waves (ACROSS). Installation of equipment and start of monitoring.	To acquire accurate data on initial state of geological conditions and rock properties before construction and changes during/after construction.	Monitoring techniques and methodologies.	improvement of system; installation, monitoring
3. Development of basis for engineering techniques in the deep underground environment				
Designing the underground facility	Planning of layout, construction schedule, engineering management (rock support and safety). Basic and detailed design studies.	To ensure that construction proceeds safely and efficiently.	Construction design.	planning of layout, schedule, engineering management; basic design; detailed design; surface preparation for shaft excavation
Planning of investigations	Planning of investigations on detection and restoration of excavation damage.	To understand possible excavation damage. To verify restoration methods.	Construction design.	planning
4. Study on long-term stability of the geological environment				
4.1 Seismological study				
Seismological monitoring	Planning, installation and monitoring with seismographs.	To accumulate data. To understand seismic activity and its relationship with seismic faults. To evaluate the effect of seismic activity on groundwater flow.	Assessment of long-term stability.	preparation of equipment; installation, monitoring
4.2 Diastrophic study				
Diastrophic monitoring	Planning, installation and monitoring with diastrophic equipment (electromagnetic surveys and GPS).	To understand regional/local diastrophic activity. To understand diastrophic history (faults, terraces, basins, sea-level).	Assessment of long-term stability.	preparation of equipment; existing data analysis; installation, monitoring
Geological investigations	Trench survey on active faults.	To understand the activity of major faults (e.g. Omagari Fault)	Assessment of long-term stability.	
Research and development on geological disposal				
1. Improvement of reliability of disposal techniques				
1.1 Verification of engineered barrier technology				
Planning of investigations in the underground facility	Laboratory tests on required precision of engineered barrier emplacement. Planning of investigations on emplacement and backfilling/plugging.	To optimize plans for barrier installation and backfilling/plugging tests.	Verification of disposal technologies	laboratory tests, basic design; detailed planning
1.2 Confirmation of design methods for engineered barrier system				
Planning of investigations in the underground facility	Literature survey on other underground laboratories. Laboratory tests (low-alkaline cement, etc.). Planning of tests on engineered barriers, gas migration, effect of cement and saline groundwater.	To optimize plans for tests on engineered barriers, gas migration, effect of cement and saline groundwater.	Development of methods for detailed design of deep repository	laboratory tests, basic design; detailed planning
1.3 Improvement of reliability of safety assessment methods				
Verification of performance assessment models	Application of scenario construction methods and performance assessment models (engineered barriers, natural barrier, biosphere) to data from surface-based investigations.	To check and improve the applicability of models to tests in the underground facility.	Improvement of reliability of performance assessment modeling	planning; application
Confirmation of requirements on geoscientific data	Sensitivity and uncertainty analysis.	To confirm the content, volume and accuracy of data required for the safety assessment.	Improvement of reliability of safety assessment methods, planning of geoscientific investigations	planning; analysis
Environmental research				
Environmental research	Literature studies and field surveys on natural and human environment (e.g. rare animals/plants, wells). Environmental monitoring.	To minimize impacts on the natural and human environment due to construction.	Construction site selection, construction design	survey; monitoring, survey
Design and construction of surface facilities				
Basic and detailed design	Design studies, ground surveys.	To construct surface facilities.	Construction of surface facilities	land preparation, research/administration office, core store, workshop; ground survey; designing of exhibition and meeting facilities
Construction	Site preparation. Construction of research/administration office, core store and workshop.	To conduct research and administrative work.	Research and administrative work	



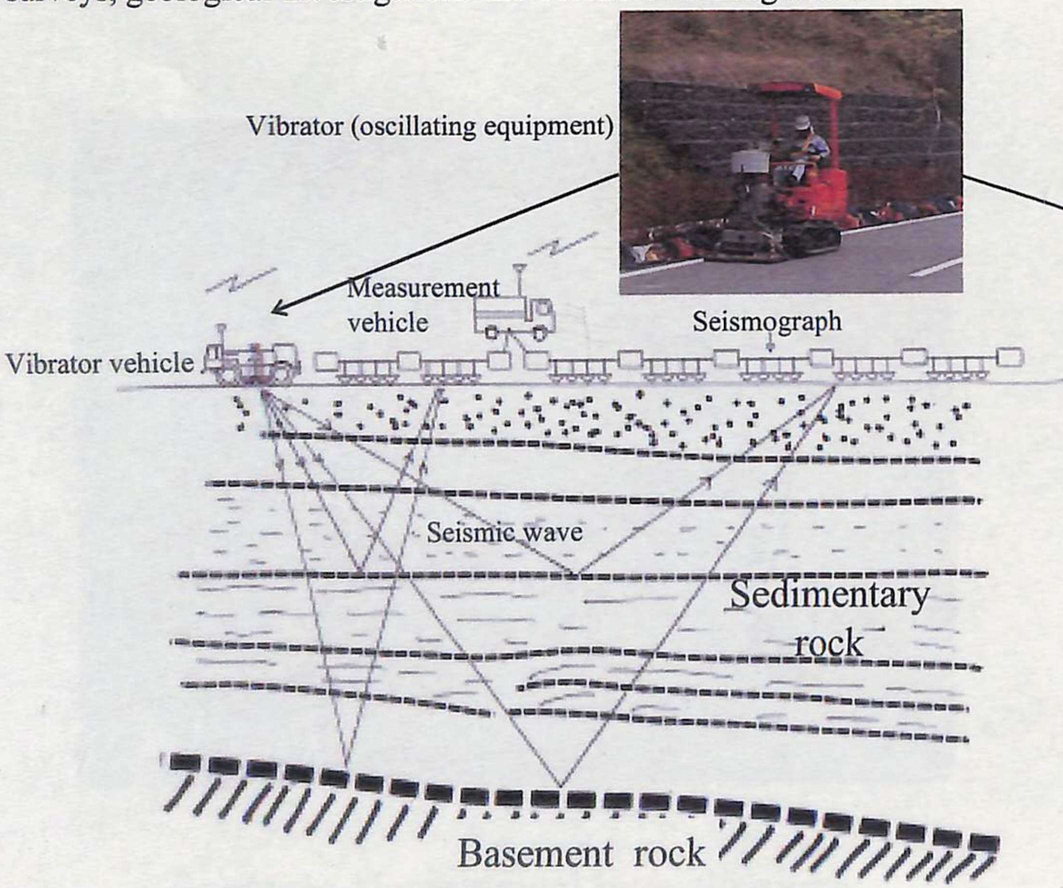
Overall Impression of the Horonobe URL Project
Surface Facilities
(Image of Laboratory)
R&D on Geological Disposal
(Backfilling of Drifts)
Concrete Plug
Clay Plug
R&D on Geological Disposal
(Engineered Barrier transport Enplacement Examination)
R&D on Geological Disposal
(Long-term Stability of Engineered Barriers and Surrounding Host Rock)
Concrete Support
Observation Drift
Electric Heater
Influence by Cement Material
Buffer Material
Propagation of Heat
Corrosion of Overpack(Carbon Steel)
Engineered Barrier Long-term stability
Geoscientific Research
(Research in Tunnel)
Injection Hole
Observation Hole
Tracer Test
Tunnel Cross Section
Geoscientific Research
(Excavation Influence Test)
Measurement of Stress, Displacement, etc.
Test Drift
Tomography Test between Boreholes
Geoscientific Research
(Geophysical Investigations)
Formation
Fault
Geoscientific Research
(Borehole Investigations)
•Core Sampling and Investigation
•Geophysical Logging etc.
Drilling Borehole
Geoscientific Research
(Rock Permeability Test)
Permeability Test Equipment
Borehole
Permeable Layer
Flow of Groundwater
Permeability Test Zone
Geoscientific Research
(Groundwater Sampling)
Groundwater Sampler
Borehole
Sampling Zone of Groundwater

Field Investigation in the 2004 fiscal year (1/6)

Geophysical investigations

High-density reflection seismic survey

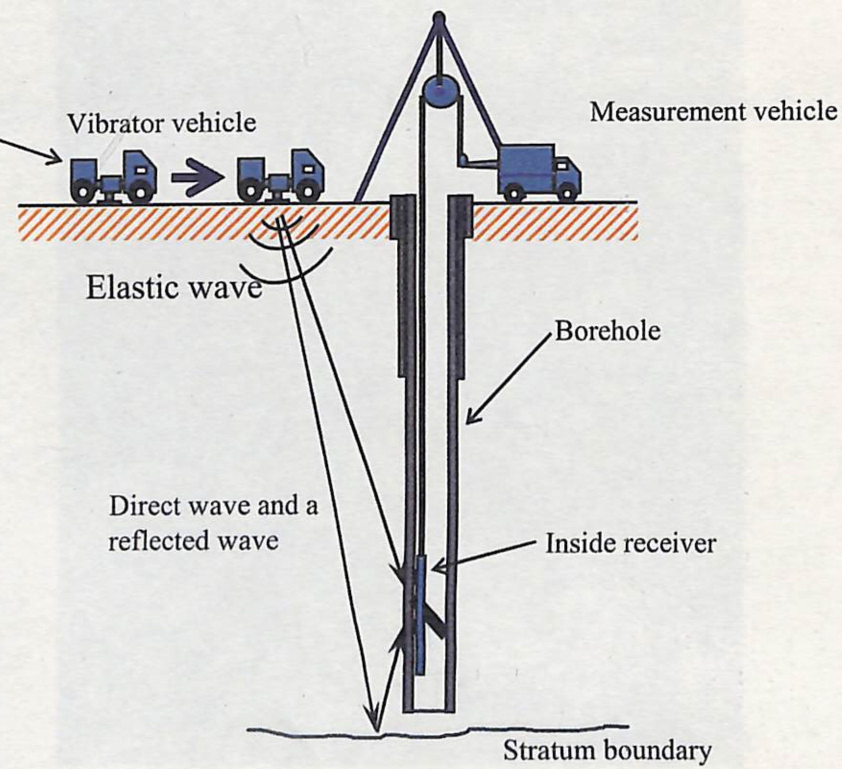
In order to understand geological structures, such as the Omagari Fault, reflection seismic and gravity surveys are performed.
Location and geometry of the Omagari Fault and other geological structures are derived from data from these and previous geophysical surveys, geological investigations and borehole investigations.



Example of a reflection seismic survey

Multi-offset VSP (Vertical Seismic Profiling survey)

VSP (Vertical Seismic Profiling) is performed using existing boreholes. By moving the position of the vibrator and establishing two or more oscillation points, detailed reflected wave data of the borehole surroundings are acquired.



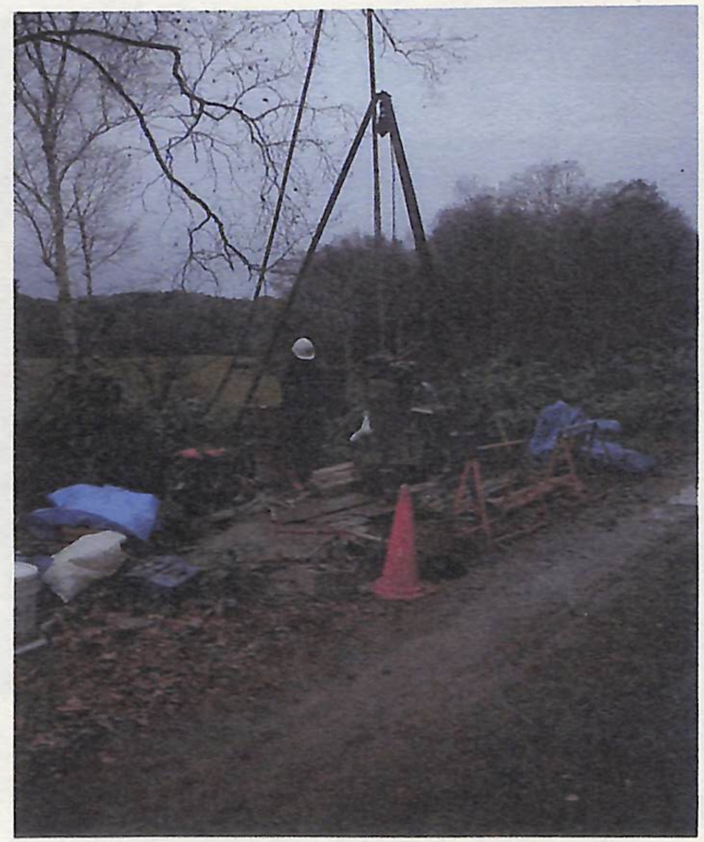
Example of a VSP survey

Field Investigation in the 2004 fiscal year (2/6)

Geological investigations

In order to clarify geological features such as distribution of stratigraphy and faults, analysis of geographical features using satellite images etc., investigation of rock samples from outcrops, and gas occurrences in shallow boreholes are investigated. The laboratory analyses comprise petrological/mineralogical and microfossil analyses.

Example of geological investigations
(Outcrop observation)

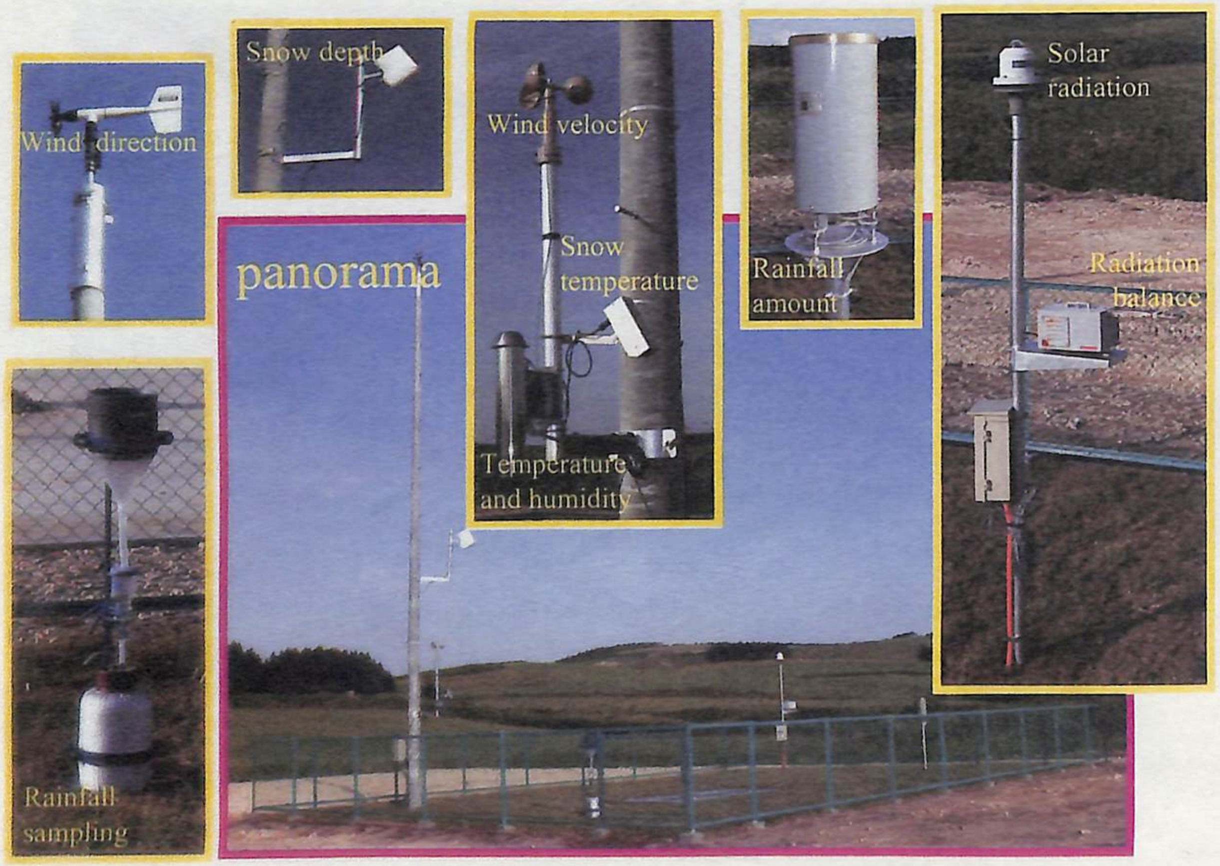


Example of borehole investigations

Field Investigation in the 2004 fiscal year (3/6)

Surface hydrological investigations

Measurement of meteorological data such as precipitation, temperature, humidity, wind velocity and direction, and evapotranspiration rate is continuing. The equipment was installed in the laboratory construction area and the surroundings by the 2003 fiscal year, measurement of river flux is also continuing. Moreover, in order to observe the distribution of groundwater level and movement of water in soil, water gauge and soil moisture meters are installed in existing and newly excavated boreholes. From these observation results and chemistry of river water and precipitation, an understanding of water movement in the near-surface environment is obtained and the extent to which rainwater permeates underground (groundwater recharge) is estimated.



Example of meteorological apparatus

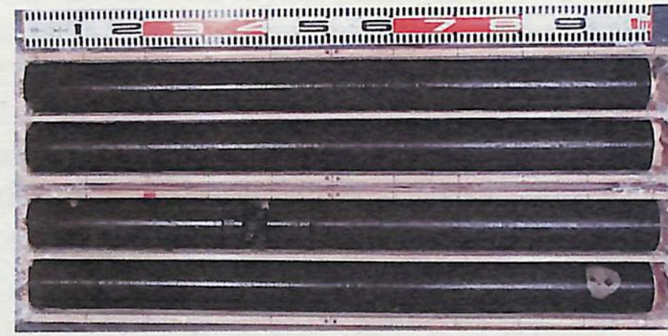
Example of river flux observation

Field Investigation in the 2004 fiscal year (4/6)

Borehole investigations

Two vertical boreholes approximately 500 m deep and one borehole with a depth of 1000 m are drilled.
All these boreholes are used to monitor groundwater pressure and chemistry before, during and after the construction of the underground facility.

Example of borehole investigations



HDB-6 core (FY 2003)
(Depth 554-558 m; Wakkanai Formation)

Groundwater analysis apparatus

Field Investigation in the 2004 fiscal year (5/6)

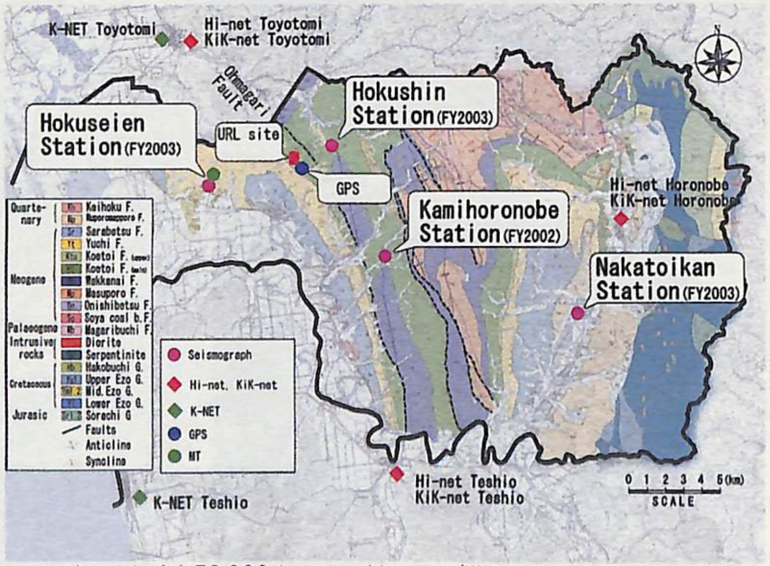
Development of investigation techniques and equipment

Drilling techniques which control the angle and direction of boreholes are developed. The applicability of geophysical survey and analysis technology in boreholes or at ground level is examined. Suitability and specifications of equipment used to measure pH-Eh and composition and amount of dissolved gas are examined for measuring under the pressure and temperature condition of deep locations in boreholes.

Methane sensor

Study on the long-term stability of the geological environment

Monitoring has started and distribution of hypocenters is being analyzed together with data from existing seismographs of other research institutes. A geological survey is carried out to determine topographical changes, deformation and weathering of geological formations. Tectonic history and climate changes around the Horonobe area are also surveyed. These data are integrated with existing information and tectonic evolution and climate changes around the Horonobe area from the Neogene to the Quaternary are documented. The amount of crustal movement and changes in electromagnetic properties deep underground are analyzed by GPS and electromagnetic measurements. These observations are performed continuously.



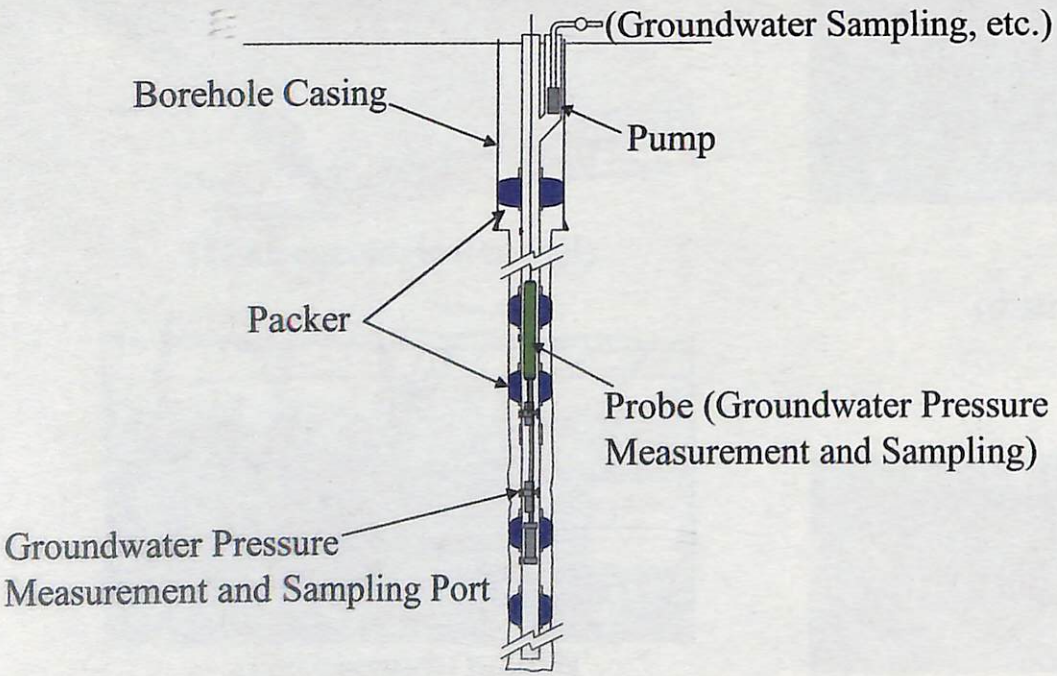
Base map is part of 1:50,000 topographic map (Wakasakanai, Toyotomi, Kamisarufutsu, Teshio, Onobunai, Pinneshiri) published by Geographical Survey Institute of Japan.

Location of observation stations in the Horonobe area

Field Investigation in the 2004 fiscal year (6/6)

Development of investigation techniques and equipment

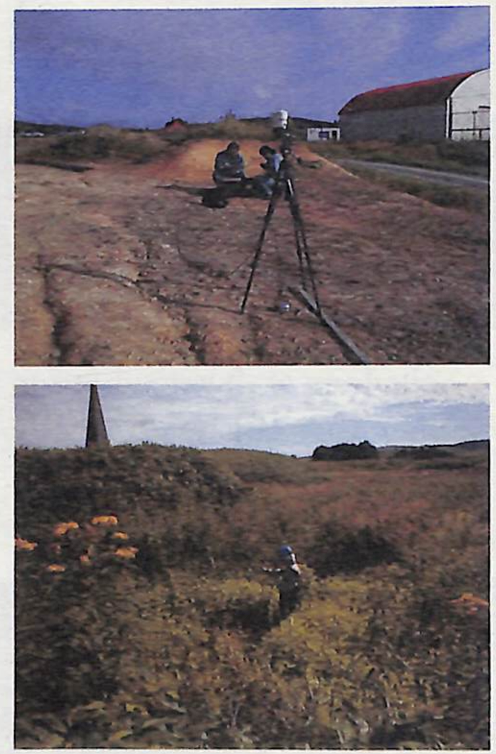
Groundwater pressure and chemistry are continuously measured before, during and after the construction of the underground facility, to determine the influences caused by construction and investigation activities. In 2004/2005, monitoring is continuing in a previously equipped borehole and equipment is being installed in the remaining boreholes. Methods for real-time description and evaluation of results are also examined.



Example of a long-term monitoring survey in a borehole

Environmental survey

Environmental surveys around the construction site (e.g. noise, vibration, water quality, etc.) are continuing.

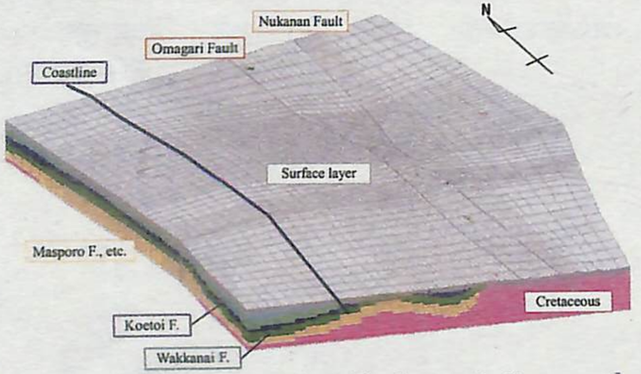


Example of a monitoring survey

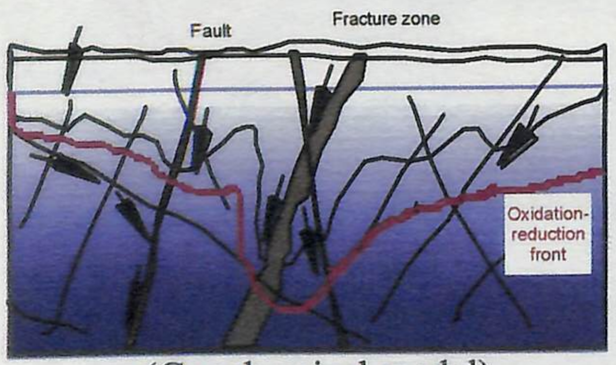
Investigations in the 2004 fiscal year (1/4)

Modeling the geological environment and predicting changes in the geological environment related to construction of the underground facilities

Based on reference data and data acquired on the geological environment, geological, hydrogeological, geochemical, and rock mechanical models are constructed and updated. Changes in the geological environment due to underground facility construction are predicted. The acquired data are registered in a database and managed systematically.

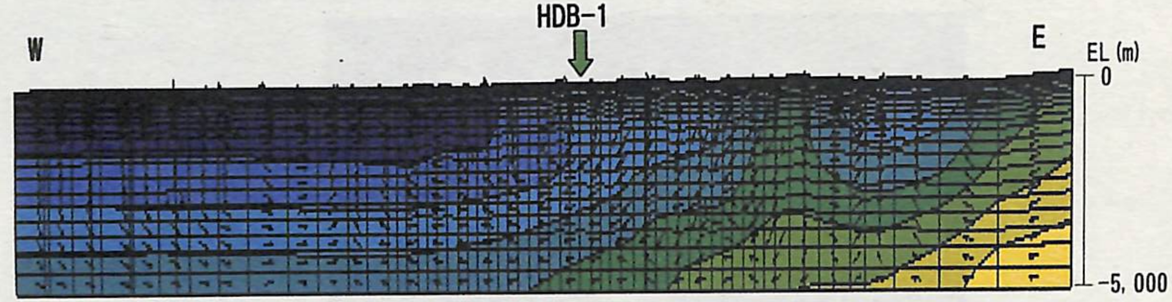


(Hydrogeological model)

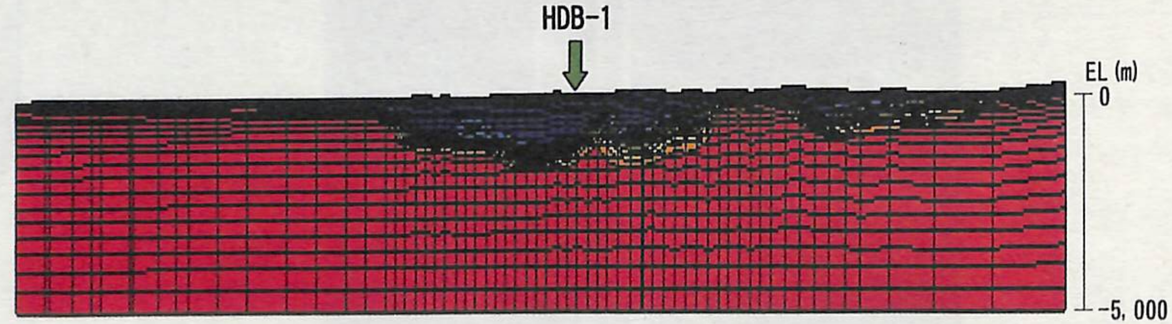


(Geochemical model)

Example of a geological environmental model



Example of groundwater flow analysis
(distribution of hydraulic head and flow velocity)



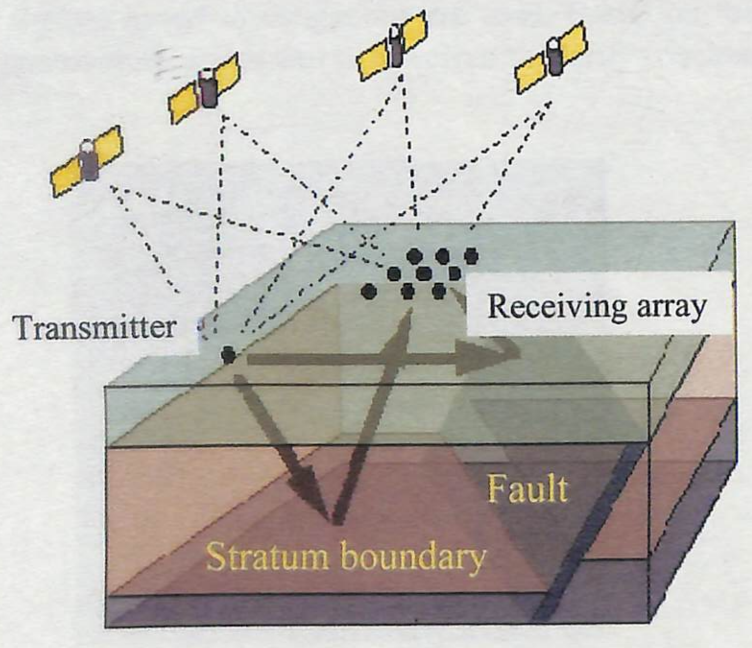
Example of groundwater flow analysis
with different densities (distribution of salinity)

Investigations in the 2004 fiscal year (2/4)

Development of investigation techniques and equipment

(Development of remotely operated monitoring system)

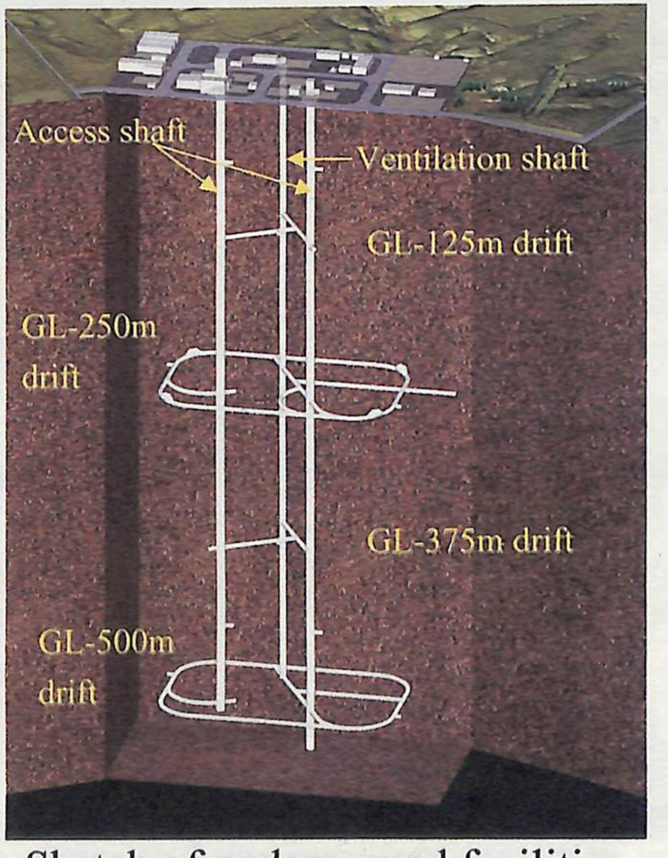
A monitoring system using seismic and electromagnetic waves will be used to monitor changes in the geological environment, such as geological structures and rock properties, before, during and after the construction of the underground facility. Test observations started in 2004/2005.



Example of a monitoring system

Development of basis for engineering techniques for deep underground

Detailed design of the underground facility is defined. It is taken into consideration that the facility should provide the opportunity for the public to experience the deep underground, as well as providing space for geoscientific investigations. Safety of the facility has the highest priority, stability of caverns with various rock properties and measures for hazard such as tunnel fire are therefore fully considered in the design.



Sketch of underground facilities

Investigations in the 2004 fiscal year (3/4)

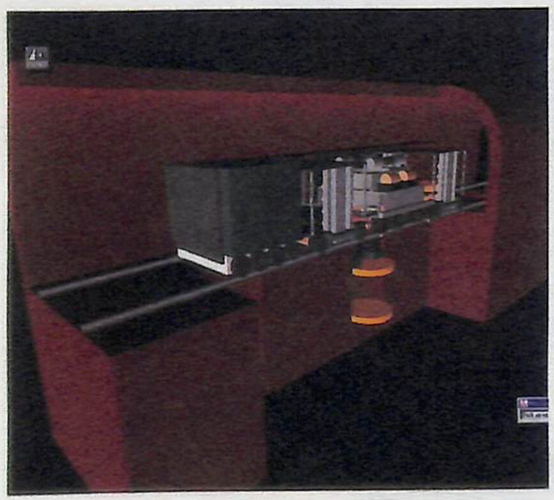
Research and development on geological disposal

•Improvement of reliability of disposal techniques

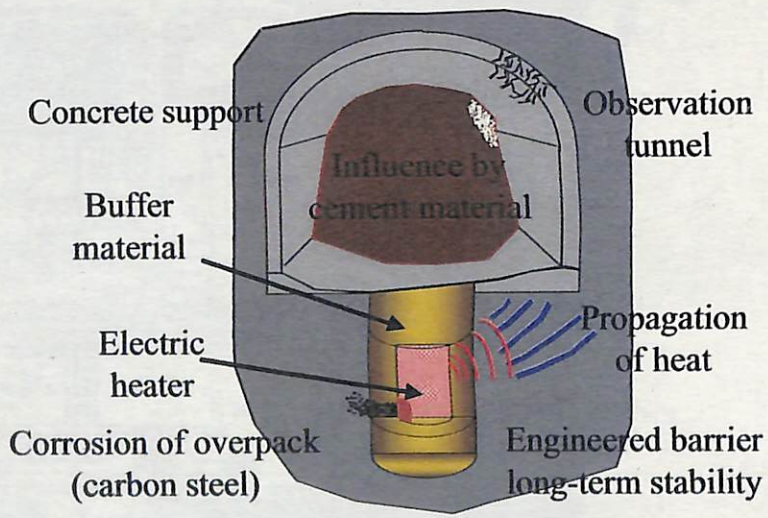
In Phases 2 and 3, investigations on transportation and emplacement of engineered barriers, rock support installation and backfilling of tunnels are planned. To make detailed plans (e.g. objectives, test items, test layout, etc.) for these investigations, laboratory tests are conducted on the precision required for the transportation and emplacement equipment and on materials such as low-alkaline concrete. Laboratory tests on corrosion of the overpack material using Horonobe groundwater are also carried out. Long-term behavior of the engineered barriers and the surrounding rock is investigated. To make detailed plans for these investigations, preliminary engineered barrier designs are carried out. Data from swelling tests on buffer material in the laboratory using Horonobe groundwater and from surface-based investigations are used in the design studies.

•Improvement of reliability of safety assessment methods

Safety assessment scenarios, models and input parameters are selected, and groundwater flow simulations, nuclide migration simulations, and uncertainty analyses are carried out. Data from migration tests on drillcore samples in the laboratory and from surface based investigations are used. Based on the results, geoscientific data and phenomena which are relevant to safety assessment, and issues to be solved to clarify requirements on quantity and accuracy of data, are identified.



Example of engineered barrier emplacement study



Research on long-term stability of engineered barriers and surrounding host rock

Investigations in the 2004 fiscal year (4/4)

Facilities arrangement plan