JNC TN5510 2005-002

Horonobe Underground Research Laboratory Project Investigation Program for the 2005 Fiscal Year (2005/2006)

May 2005

Japan Nuclear Cycle Development Institute
Horonobe Underground Research Center

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(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 (Phase 3). The 2005 fiscal year is the sixth (and final) year of the Phase 1 investigations and the first year of the Phase 2 investigations.

Geophysical, geological, surface hydrogeological and borehole investigations are carried out in order to develop techniques for exploring the geological environment. Based on the acquired data, geological environment models are constructed, revised and verified.

As part of the development of techniques for monitoring the geological environment, long-term monitoring of groundwater pressures is ongoing in boreholes drilled in a previous investigation. Long-term monitoring systems are also installed in the remaining boreholes. A remotely operated monitoring system (ACROSS) is also installed and tested.

Studies on the long-term stability of the geological environment include monitoring with seismographs, GPS and equipments of electromagnetic survey.

Engineering techniques for application in the deep underground environment will be developed during construction of the underground facilities.

To provide input for detailed planning of the Phase 2 and 3 investigations, laboratory tests are carried out on tunnel reinforcement materials.

With a view to improving their reliability, safety assessment methods are examined using field and laboratory data.

Construction of the surface facilities, initiated in the previous fiscal year, is ongoing and the work on the public information house is started.

Environmental monitoring is ongoing. Collaboration with domestic and overseas research institutes continues to form an important part of the program.

* Horonobe Underground Research Center Coordination Group

[1] This document is an English translation of Technical Document JNC TN5400 2004-007.

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2005 年 5 月

幌延深地層研究計画　平成 17 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 17 年度は、地上からの調査研究段階（第 1 段階）の 6 年目(最終年度)であり、第 2 段階の 1 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の開発では、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)の設置および試験観測を実施する。

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、地下施設の建設に着手する。

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、覆工材料に関する室内試験を実施する。

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、前年度に引き続き造成工事および建屋の建設工事を実施し，PR 施設の建設に着手する。

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 2004-007 幌延深地層研究計画 平成 17 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 for 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). Research and development on geological disposal technologies and on establishing reliable methodologies for safety assessment are executed in these facilities. These facilities 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 of Technology Base for Atomic Energy" (Atomic Energy Subcommittee of the Advisory Committee for Natural Resources and Energy, 2001), states that JNC should promote research and development (i.e. scientific studies of the deep geological environment, improving the reliability of geological disposal technologies and refinement of safety assessment methods) through acquisition of 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 three R&D areas mentioned above as being part of JNC's responsibility correspond to the areas "Geoscientific Research" and "Research and Development on Geological Disposal" which form 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 (Phase 3). This report summarizes the investigation program for the 2005 fiscal year (2005/2006), the sixth (and final) year of the Phase 1 investigations, and the first year of the Phase 2 investigations.

The investigations in 2005/2006 are focused on the Hokushin area, which was selected as the area for laboratory construction. The main investigation region extends over approximately 3×3 km^2.

The summarization of the Phase 1 investigations includes a synthesis of research results obtained so far, construction and update of geological environment models and predicting changes in the geological environment caused by construction of the underground facilities.

2. Outline of the investigation program for 2005/2006

Geophysical, geological, surface hydrogeological and borehole investigations are carried out to acquire the geoscientific data needed to develop techniques for investigating the geological environment. Together with previously existing information, the data acquired in this phase are used to construct and refine models of the geological environment and to predict changes in the geological environment caused by construction of the underground facilities.

As part of the program for developing techniques for monitoring the geological environment, groundwater pressures have been observed using a long-term monitoring system in a borehole until the 2004 fiscal year; it is now planned to install such systems in the remaining boreholes at the site. A remote monitoring system has also been installed and test observations are carried out.

The instruments such as borehole and surface seismographs, GPS[3] (Global Positioning System) and equipments of electromagnetic survey[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 alkaline concrete materials are 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 investigated.

In the 2005 fiscal year, the results from refined models of the geological environment and from prediction of changes caused by construction of the underground facilities are used to specify the detailed research program for Phase 2.

Construction of the underground facility provides the opportunity for developing engineering techniques relevant for the deep underground environment.

Development of the construction site was initiated in the 2004 fiscal year. Work on a research and development center and a core storage/workshop[5] are underway and construction of public information house has also begun.

Monitoring of environmental parameters has been ongoing since 2001.

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

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

[4] The primary electromagnetic field, originating from sunspot activity, generates a secondary electromagnetic field on reaching the earth. The electromagnetic survey method is used to investigate sub-surface geological structures.

[5] The building for storage of drillcores and storage and maintenance of investigation equipment.

3. Geoscientific research

3.1. Development of techniques for investigating the geological environment

3.1.1. Acquisition of geoscientific data

In 2005/2006, borehole investigations are carried out to acquire data on geological structure, stratigraphy, hydraulic properties, groundwater chemistry and rock mechanical properties. Measurement of meteorological data, river flux, groundwater level and soil moisture meter are also continuing. The equipment was installed in the laboratory construction area and surroundings until the 2004 fiscal year. These observations, together with water quality analyses of rivers and precipitation, provide comprehensive surface hydrological data. Details are described in the following sections.

(1) Geophysical investigations

It was confirmed from the results of electromagnetic sounding that had been carried out at the estimated position of the Omagari Fault in 2003 that there was a higher resistivity zone into deep underground. In 2005, an electrical survey aimed at measuring resistivity in the formations of the shallow underground is carried out to investigate the distribution of this high resistivity zone.

(2) Geological investigations

In order to clarify parameters such as stratigraphic distribution and occurrence of faults, geographical features are analyzed by investigating rock samples from outcrops and gas occurrences in shallow boreholes drilled in 2003/2004. Laboratory studies include petrological/mineralogical and microfossil analyses.

(3) Surface hydrogeological investigations

Collection of meteorological data, including precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rates, is continuing. The relevant equipment was installed in the laboratory construction area and surroundings by the 2004 fiscal year. Measurement of river flux is also continuing. 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 chemical analyses of river water and precipitation, movement of water in the shallow underground environment can be understood.

(4) Borehole investigations

A vertical borehole with a depth of approximately 1000 m (HDB-11) has been drilled since 2004 and laboratory tests are carried out on the drillcores. Field tests in this borehole will also be carried out during and after the construction of the underground facilities. The program includes the following:

a) Drillcore investigations

- Geological characterization: core description (lithology, fractures, etc.), petrographical/mineralogical investigations, chemical analysis, age dating and microfossil (such as diatom) 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 permeability tests in the laboratory.
- Groundwater chemistry: porewater extraction and chemical analysis (using drillcores).

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 properties: tests to determine hydraulic permeability and head distribution.

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

Geological, hydrogeological, hydrochemical and rock mechanical models have been constructed and refined, based on literature data and data on the geological environment acquired up to 2004. 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 existing geological model, which describes the distribution of sedimentary formations, faults and folds, will be evaluated and revised using new data from geophysical surveys, geological investigations and borehole investigations carried out up to the 2004 fiscal year.

(2) Hydrogeological model

A hydrogeological model of the laboratory construction area and surroundings was revised based on existing models and data from the borehole investigations conducted up to 2004. The volume of inflow and changes in groundwater pressure caused by construction of the underground facilities are predicted using this revised 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 on drillcores and measurements in boreholes; these data were acquired up to 2005. The model is used to evaluate the stability of rock caverns. Changes in rock mechanical properties caused by the construction of underground facilities are predicted using this model.

3.1.3. Development of investigation techniques and equipment

Borehole drilling and development of investigation techniques and equipment are currently underway.

Drilling techniques capable of controlling the angle and direction of boreholes (controlled drilling) are developed. The controlled drilling carried out in 2003/2004 in the Hokushin area is continuing and in 2006, controlled drilling planned for the Omagari Fault will start in the Kami-Horonobe area. The plan for the 2005 fiscal year includes, in addition to a literature survey, geological investigations, geophysical surveys (seismic reflection surveys) and shallow borehole investigations (two or three boreholes approximately 50 m deep).

The applicability of geophysical and analytical techniques in boreholes and at ground surface is also examined at Hokushin and in the western part of the Horonobe area.

In-situ measurement of pH, redox potential (Eh) and dissolved gas has been carried out. The applicability of the equipment used to measure these properties in deep boreholes is examined.

The applicability of the investigation techniques used in Phase 1 is also examined and results are synthesized.

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 before, during and after the construction of the underground facilities to determine the influence of the construction. In 2005/2006, monitoring will continue in a borehole equipped in 2004; equipment for monitoring groundwater pressure is also installed in the remaining boreholes at the site. Methods for real-time description and evaluation of results are also examined.

3.2.2. Development of a 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 facilities. Test observations are currently ongoing.

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

3.3.1. Seismological studies

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

3.3.2. Diastrophic study

A survey is carried out to obtain information on topographical changes, fault activity, deformation processes and the weathering of geological formations. The tectonic history and climate changes in the Horonobe area are also 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 the Quaternary.

The amount of crustal movement and changes in electromagnetic properties of 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 will be conducted on materials used for tunnel support and backfilling. To make detailed plans for these investigations (e.g. objectives, test items, test layout, etc.), laboratory tests are carried on workability of materials such as low-alkaline concrete.

4.1.2. Confirmation of designing methods of engineered barrier

The long-term behavior of the engineered barrier system and the surrounding rock will be investigated in Phases 2 and 3. In preparation for these investigations, studies on the specifications of the engineered barrier system are carried out for the in-situ experiments. Data from surface-based investigations are also used in these studies.

4.2. Improving the reliability of safety assessment methodologies

Scenarios and models for safety assessment, and associated input parameters, are first selected. Based on these, simulations of groundwater flow and nuclide migration are then carried out and analysis methodologies are improved taking into consideration identified uncertainties (uncertainty analysis[6]). Data from radionuclide migration tests carried out on drillcore samples in the laboratory and from surface-based investigations are used in these studies. Based on the results, the geoscientific data and phenomena which are relevant to safety assessment, and requirements in terms of quantity and accuracy of data, are identified.

5. Investigation program for Phase 2

A detailed investigation program for Phase 2 has been drawn up based on the result of the geological environment model updates and predictions of the influence of constructing the underground facilities.

In the 2005 fiscal year, preparation of the temporary infrastructure (power supply, etc.) required for constructing the underground facilities and construction of the ventilation shaft are began.

6. Surface facilities and environmental surveys

6.1. Surface facilities

Development of the construction site (mainly landscaping work) is continued since 2004. Construction of a research and administration office and a core storage/workshop is underway; construction of a public information house has also begun. The yard of surplus soil (i.e. muck from construction of the underground facilities) is also made.

6.2. Environmental survey

Monitoring of relevant environmental parameters (e.g. noise, vibration, water properties) is now ongoing in the area around the URL site.

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

7. Collaboration with other research organizations

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

Collaborative research will be conducted with the organizations listed below.

- **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)
- **Radioactive Waste Management Funding and Research Center (RWMC)**[7] for studies of applicability of high-precision geophysical survey
- **Institute of Research and Innovation (IRI)**[8] for studies of hydrogeology and groundwater chemistry
- **Shizuoka University** for analysis and quantitative evaluation of microbes 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
- **Okayama University** for studies of measurement methods for groundwater flow direction and velocity
- **National Cooperative for the Disposal of Radioactive Waste (Nagra)**[10] (Switzerland) for development of hydrogeological borehole investigation techniques
- **National Radioactive Waste Management Agency (Andra)**[11] (France): active consideration of topics for cooperative studies is underway.

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 (H-RISE)**[12]**.**

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[7] RWMC was established in 1976 as a specialized research institute for radioactive waste management. In November 2000, RWMC was designated as the organization responsible for the administration of the final disposal reserve funds for high-level radioactive waste.

[8] IRI was established to investigate creation of industrial technologies and neo-social systems in 1964. Research and development in the nuclear fuel cycle field is now covered by its activities.

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

[10] Nagra is responsible for geological disposal research in Switzerland. A key part of its program includes in-situ investigations in domestic underground rock laboratories (e.g. Grimsel).

[11] In France, Andra plays a key role in the R&D on high-level and intermediate-level (long-lived) radioactive waste disposal. Andra is carrying out an underground research laboratory project in sedimentary rock (same rock type as Horonobe).

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

References

Atomic Energy Commission of Japan: "Long-term Program for Research, Development and Utilization of Nuclear Energy" (in Japanese), (1994).

Atomic Energy Commission of Japan: "Long-term Program for Research, Development and Utilization of Nuclear Energy" (in Japanese), (2000).

Atomic Energy Subcommittee of the Advisory Committee for Natural Resources and Energy: "Securing of Technological Base in Atomic Energy" (in Japanese), (2001).

Japan Nuclear Cycle Development Institute: "Horonobe Underground Research Laboratory Project, Investigation Program for the 2005 Fiscal Year (2005/2006)" (in Japanese), Technical Document JNC TN5400 2004-007, (2005).

APPENDIX

Overview of the surface-based investigations (Phase 1)

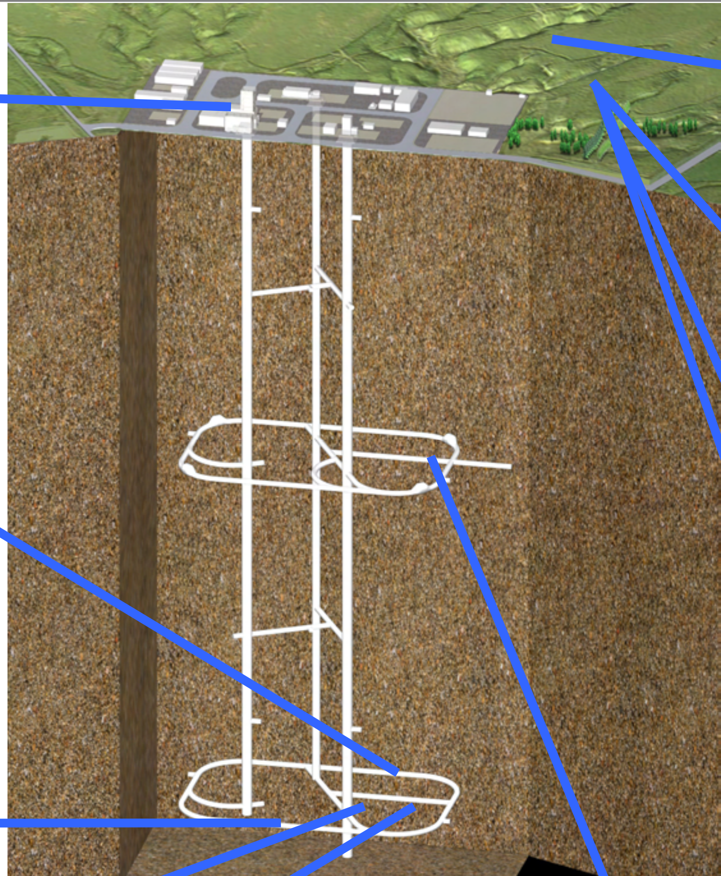
Items	Content	Objectives	Application of results	2000FY (H12)	2001FY (H13)	2002FY (H14)	2003FY (H15)	2004FY (H16)	2005FY (H17)
					Surface-based investigations (Phase 1)	area selection			(Phase 2)
				Selection of area for URL construction			Investigations in/around the selected area		
Geoscientific Research									
1. Development of techniques for investigating 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. Construction 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 the geological environment and prediction changes caused by construction of the underground facilities									
(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 investigation techniques 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 sampling 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.		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)	2001FY (H13)	2002FY (H14)	2003FY (H15)	2004FY (H16)	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 long-term monitoring of 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 a 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 technology									
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						

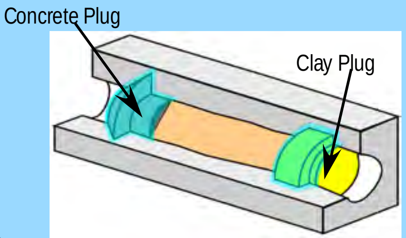
Overall impression of the Horonobe URL Project



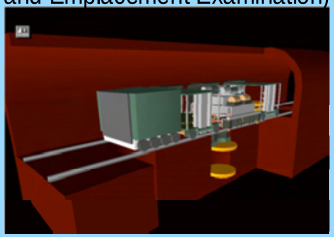
*** This figure may be changed depending on the results of future investigations.**

Surface Facilities
(Image of Laboratory)

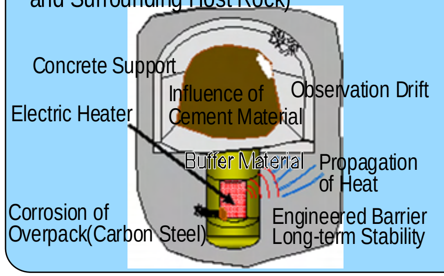
R&D on Geological Disposal
(Backfilling of Drifts)



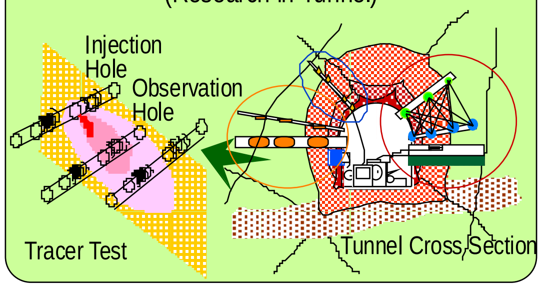
R&D on Geological Disposal
(Engineered Barrier Transport and Emplacement Examination)



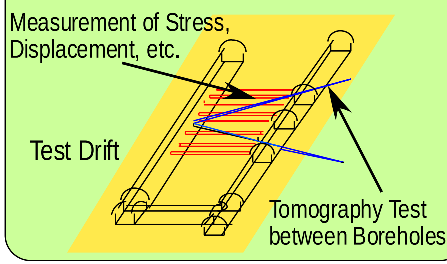
R&D on Geological Disposal
(Long-term Stability of Engineered Barriers and Surrounding Host Rock)



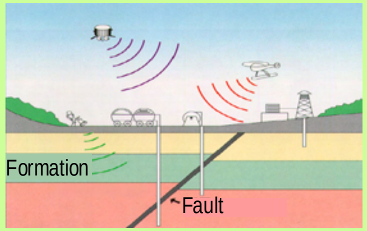
Geoscientific Research
(Research in Tunnel)



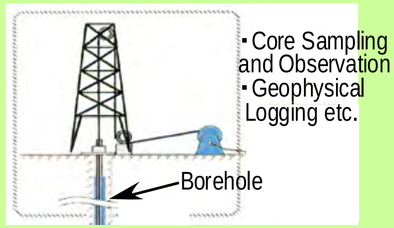
Geoscientific Research
(Excavation Influence Test)



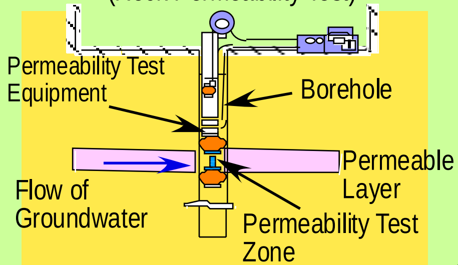
Geoscientific Research
(Geophysical Investigations)



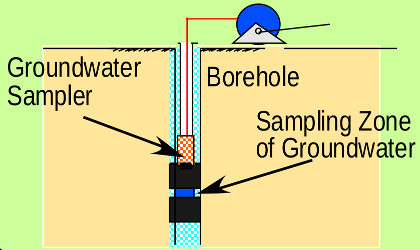
Geoscientific Research
(Borehole Investigations)



Geoscientific Research
(Rock Permeability Test)



Geoscientific Research
(Groundwater Sampling)

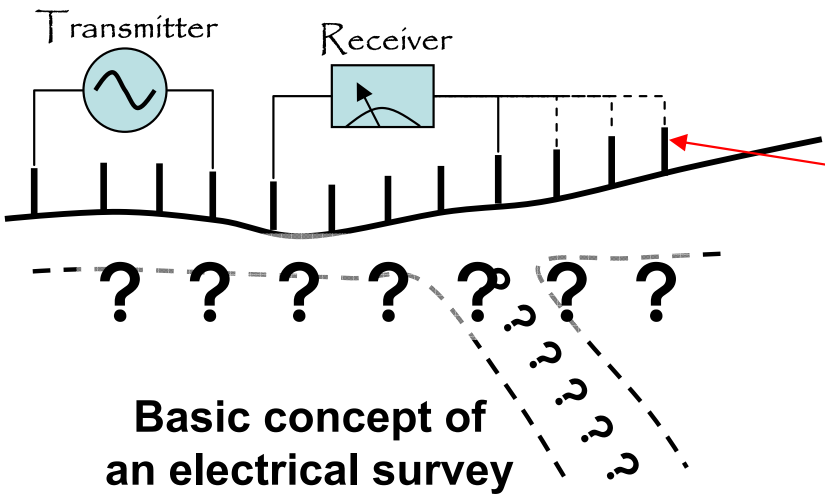


Field Investigations in the 2005 Fiscal Year (1/8)

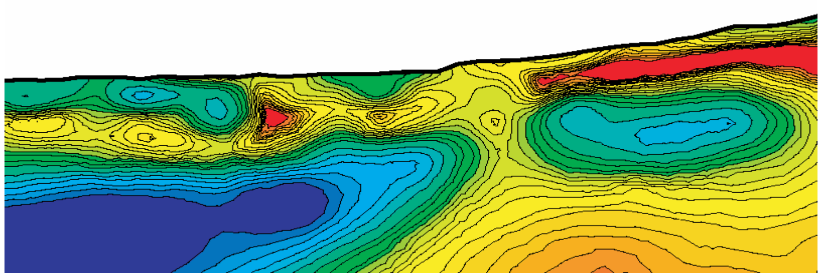
Geophysical investigations

Electrical Survey

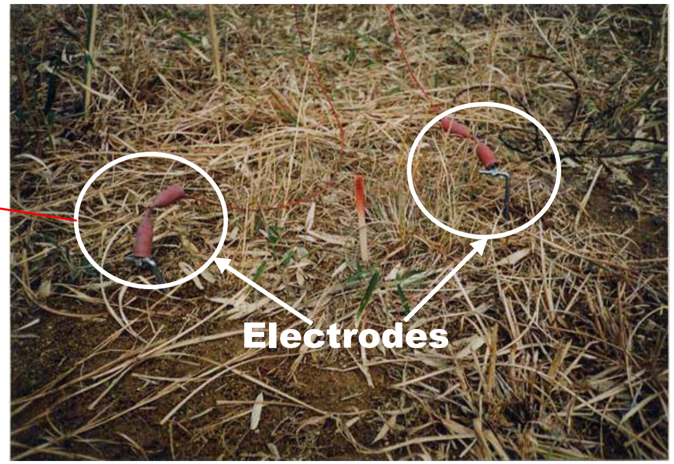
A higher resistivity zone was detected by an electromagnetic survey around the estimated location of the Omagari Fault in 2003.
In 2005, an electrical survey aimed at measuring resistivity is carried out to investigate the distribution of this higher resistivity zone in shallower formations.



Basic concept of an electrical survey



Underground Resistivity distribution



Installed measuring electrodes

Field Investigations in the 2005 Fiscal Year (2/8)

Geological investigations

In order to clarify geological features such as distribution of stratigraphy and faults, rock samples from outcrops and gas occurrences are investigated at the surface and in shallow boreholes. Petrological/mineralogical and microfossil analyses are carried out in the laboratory.

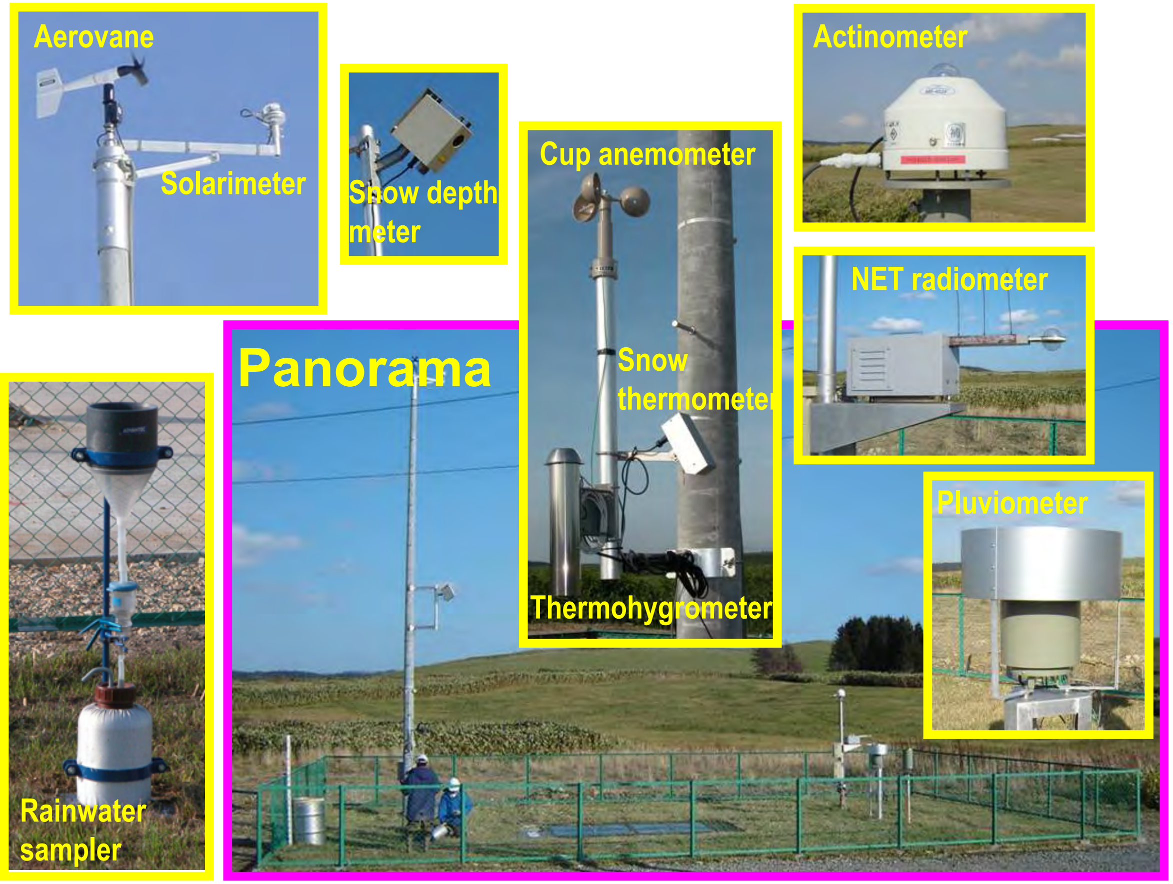
Field observation of Omagari Fault at Kami-Horonobe

Gas collection using vinyl chloride pipe

Field Investigations in the 2004 Fiscal Year (3/8)

Surface hydrological investigations

Collection of meteorological data (precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rate) is continuing. The relevant equipment was installed in the laboratory construction area and surroundings in the 2004 fiscal year. Measurement of river flux is also continuing. In order to determine the distribution and flow of near-surface groundwater, water level meters and a soil moisture meter have been installed in both existing and newly excavated boreholes. From the results of these observations and the chemistry of river water and precipitation, movement of water in the shallow underground environment can be understood.



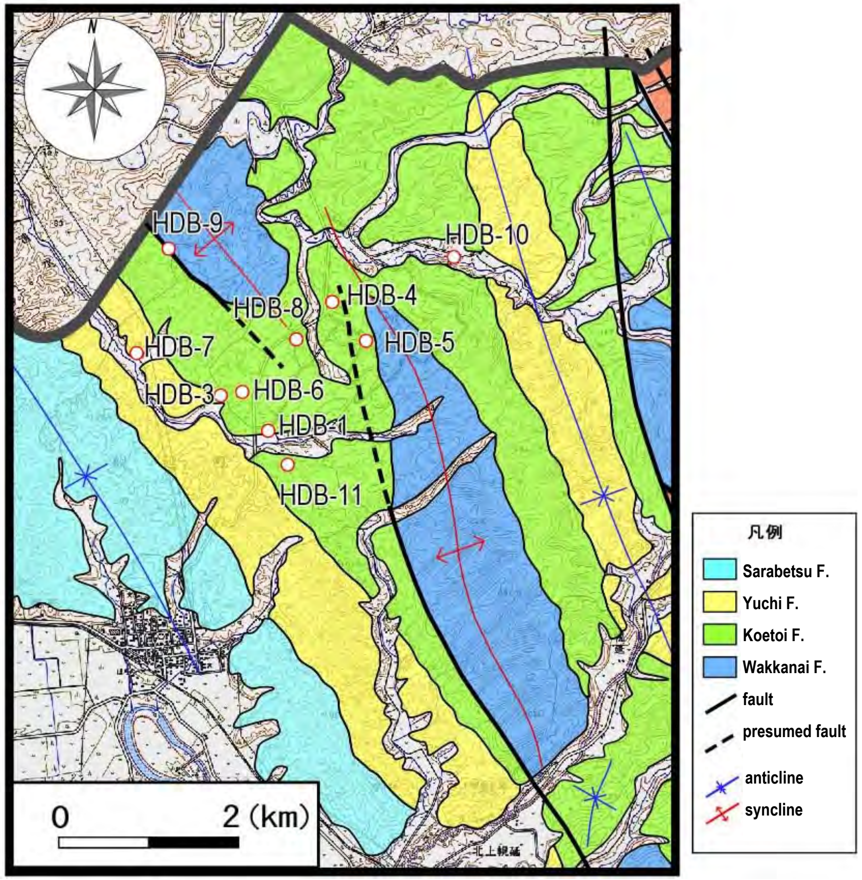
Meteorological apparatus

River flux observation

Field Investigations in the 2005 Fiscal Year (4/8)

Borehole investigations

A vertical borehole with a depth of approximately 1000 m (HDB-11) has been drilled since 2004. Laboratory tests on drillcores are carried out. During and after the construction of the underground facilities, field tests will also be carried out in this borehole.



Base map is part of the 1:50,000 topographic map (Toyotomi, Onobunai) published by the Geographical Survey Institute.

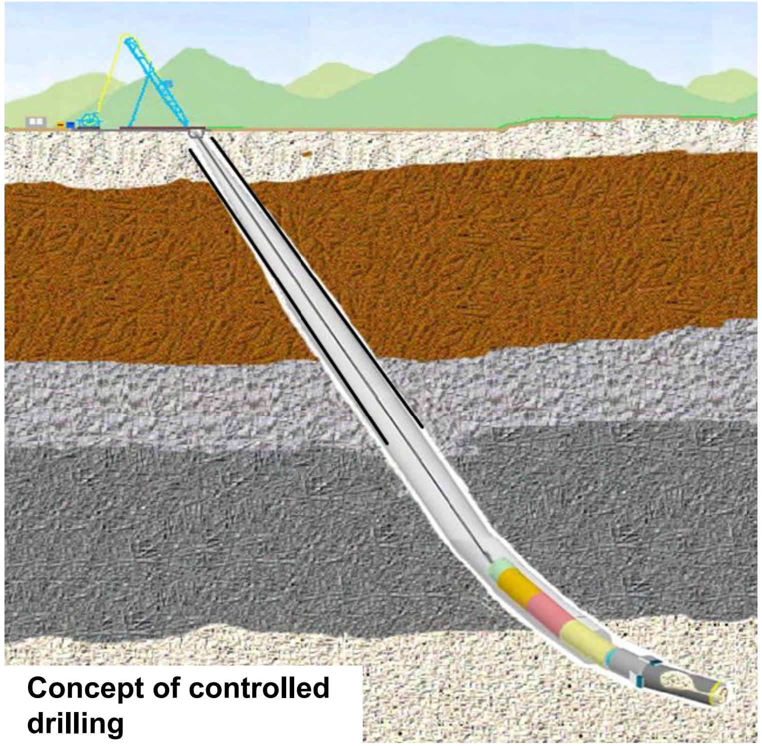
Positional chart for each borehole investigation

Borehole investigation at the HDB-11

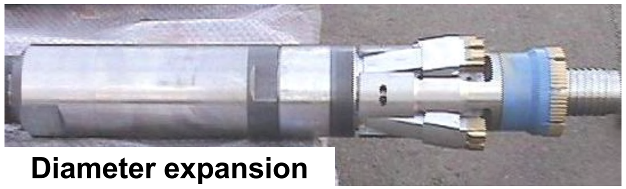
Field Investigations in the 2005 Fiscal Year (5/8)

Development of investigation techniques and equipment

Borehole drilling and development of investigation techniques and equipment are ongoing.
Drilling techniques which can control the angle and direction of boreholes (controlled drilling) are developed.
The applicability of geophysical and analytical techniques in boreholes and at ground surface is also examined.
In-situ measurement of pH, redox potential (Eh) and dissolved gas has been carried out. The suitability of equipment used to measure these properties is examined for application under in-situ conditions in deep boreholes.



Concept of controlled drilling



Diameter expansion

Methane sensor

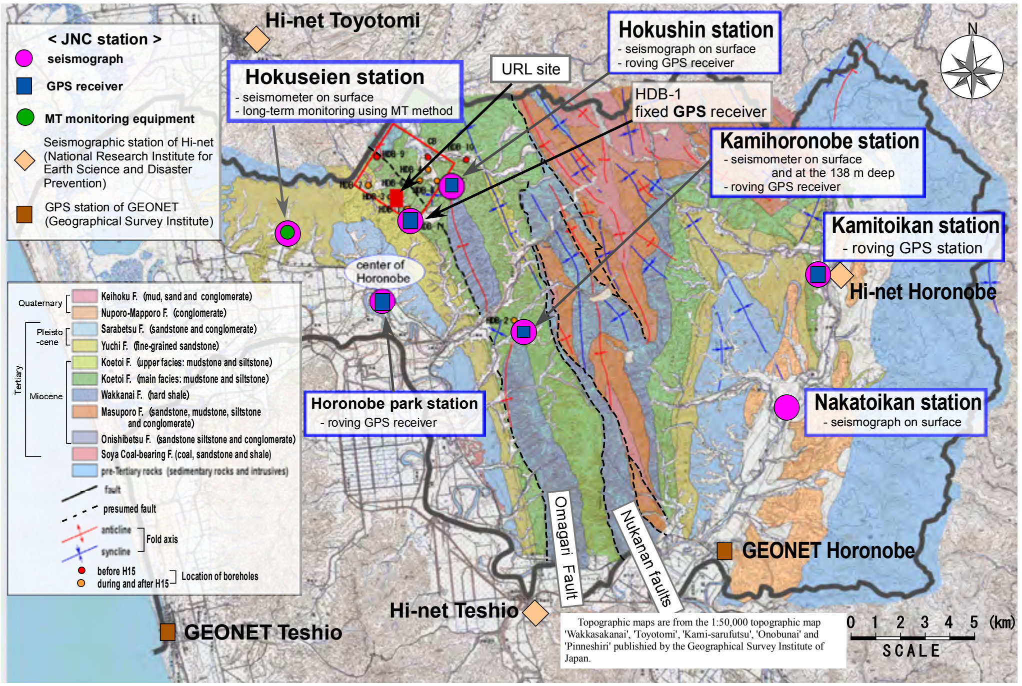
Field Investigations in the 2005 Fiscal Year (6/8)

Study on the long-term stability of the geological environment

Seismographs were installed at ground surface and at the bottom of 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 analyzed; the results are integrated with data from existing seismograph systems set up by other research institutes and universities.

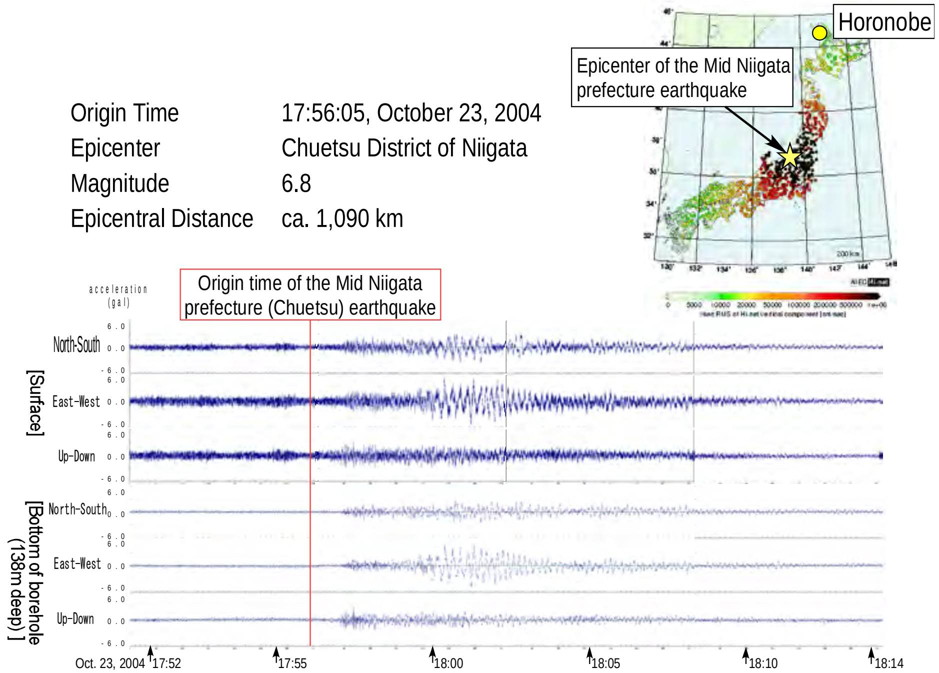
A survey is carried out to obtain information on topographical changes, fault activity, deformation processes and the weathering of geological formations. The tectonic history and climate changes in the Horonobe area are also investigated. These data are integrated with existing information to provide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

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

Location of observation stations in the Horonobe area



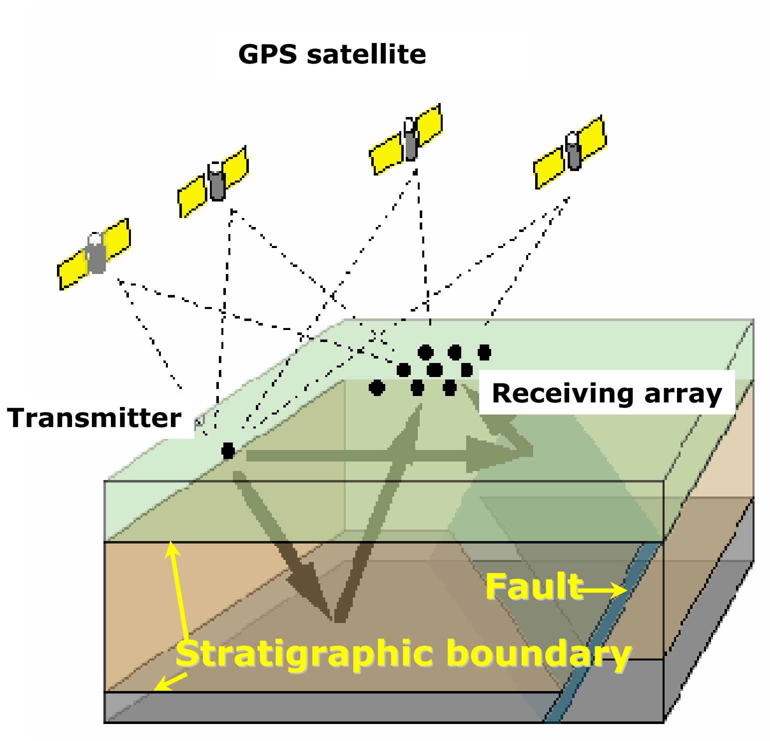
Extract from data on the website of the National Research Institute for Earth Science and Disaster Prevention of Japan (http://www.hinet.bosai.go.jp/)

Earthquake observation (Mid Niigata prefecture earthquake in 2004)

Field Investigations in the 2005 Fiscal Year (7/8)

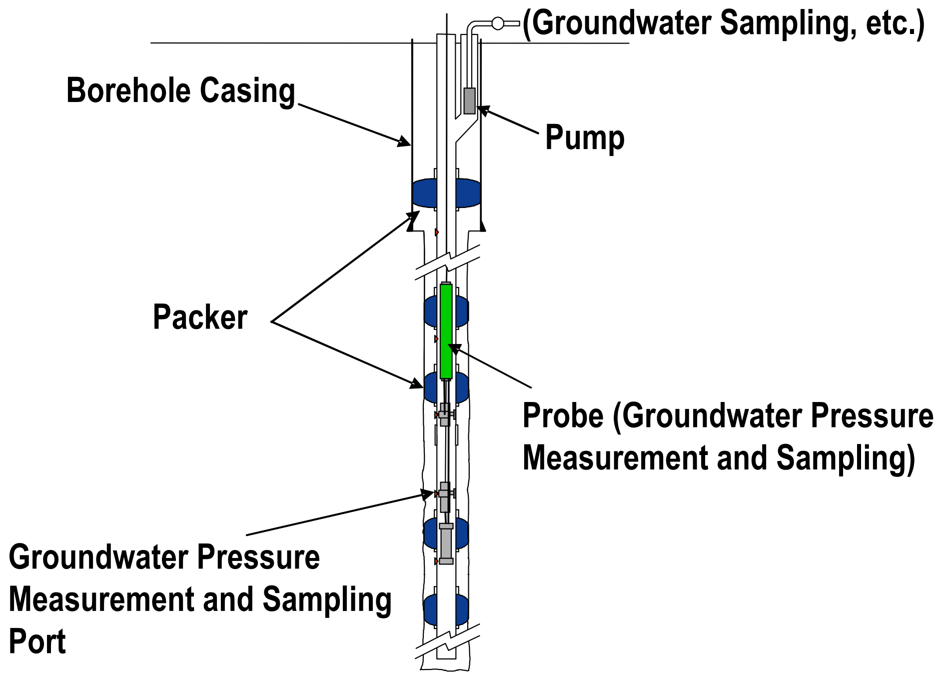
Development of techniques for long-term monitoring of the geological environment

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 construction of the underground facilities.
Test observations are ongoing in 2005/2006.



Remote monitoring system

Groundwater pressure and chemistry are measured before, during and after the construction of the underground facilities to determine the influence of investigation and construction activities. In 2005, monitoring will continue in a borehole equipped in 2004; equipment for monitoring groundwater pressure is also installed in the remaining boreholes at the site. Methods for real-time description and evaluation of results are also examined.



Long-term monitoring survey in a borehole

Field Investigations in the 2005 Fiscal Year (8/8)

Environmental survey

Monitoring of environmental parameters (e.g. noise, vibration, water properties) is ongoing in the area around the URL site.

Noise and vibration survey

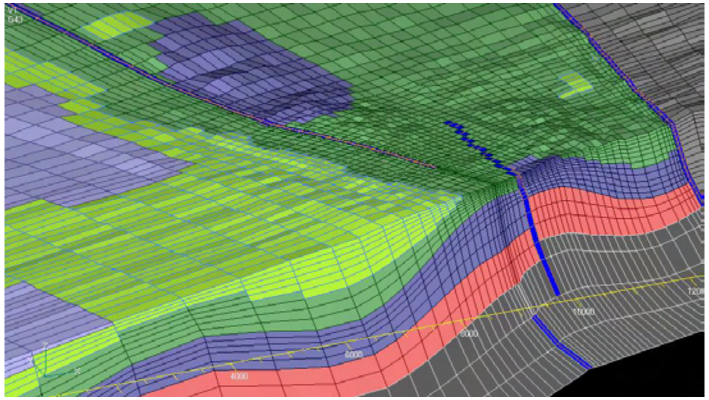
Transplantation of Torreyocholoa viridis

Environmental surveys

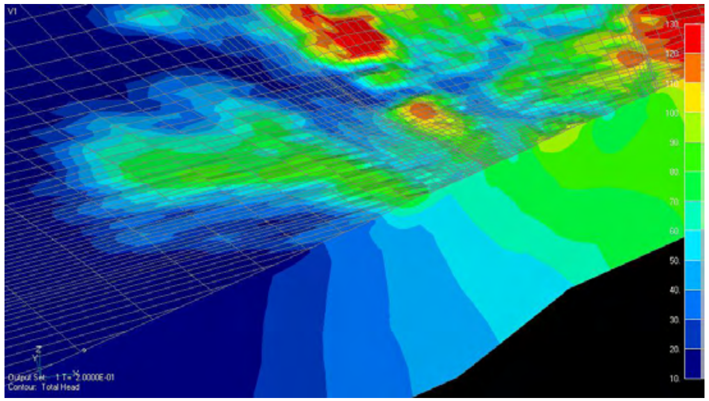
Investigations in the 2005 Fiscal Year (1/7)

Modeling the geological environment and predicting changes caused by construction of the underground facilities

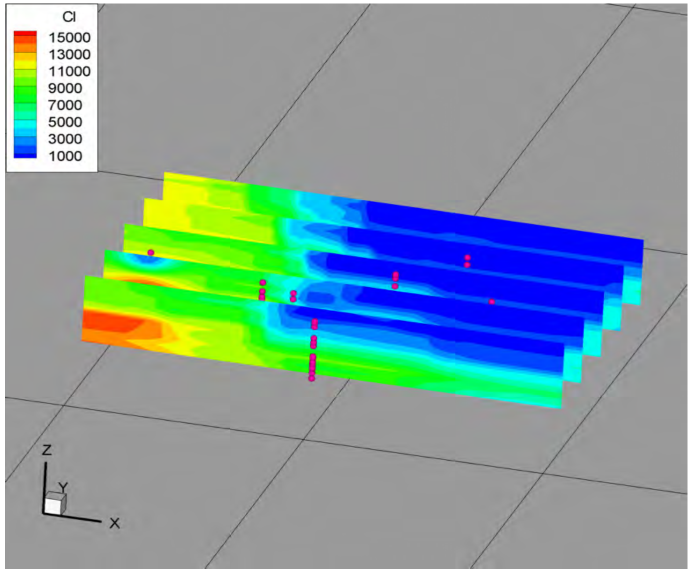
Geological, hydrogeological, hydrochemical and rock mechanical models have been constructed and refined, based on literature data and data on the geological environment acquired up to 2004. Changes in rock properties, groundwater flow and groundwater chemistry caused by the construction of the underground facilities are predicted using these models. All data are stored and managed in a comprehensive database system.



Geological environmental model (hydrogeological model)



Total head distribution of groundwater



Geochemical model (concentration distribution of chloride)

Investigations in the 2005 Fiscal Year (2/7)

Research and development on geological disposal

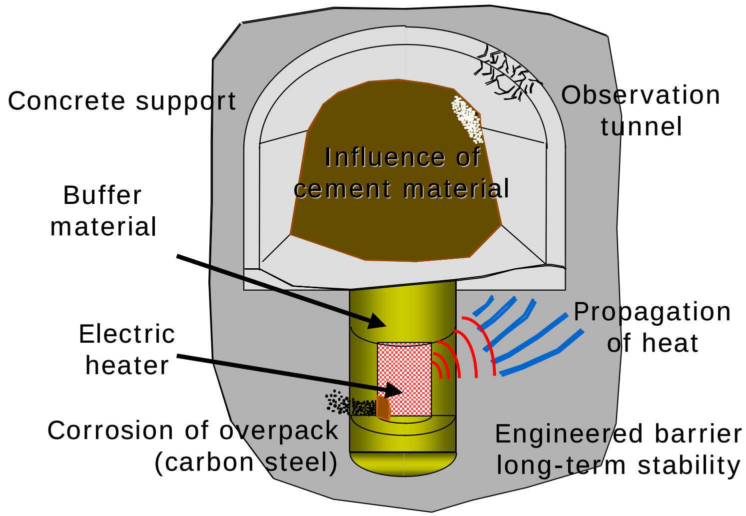
•Improving the reliability of disposal techniques

In Phases 2 and 3, investigations on the materials for tunnel support and backfilling are foreseen. To make detailed plans for these investigations (e.g. objectives, test items, test layout, etc.), laboratory tests are carried out on the workability of materials such as low-alkaline concrete. The long-term behavior of the engineered barriers and the surrounding rock will be investigated in Phases 2 and 3. In preparation for these investigations, studies of specifications of the engineered barrier system are carried out for the in-situ experiments. Data from surface-based investigations are used in these studies.

•Improving the reliability of safety assessment methodologies

Scenarios and models for safety assessment, and associated input parameters, are first selected. Based on these, simulations of groundwater flow and nuclide migration are then carried out. Analysis methods are then improved taking the identified uncertainties into consideration (uncertainty analysis). 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 volume and accuracy of data are identified.

Migration test in the laboratory (QUALITY, Tokai works)



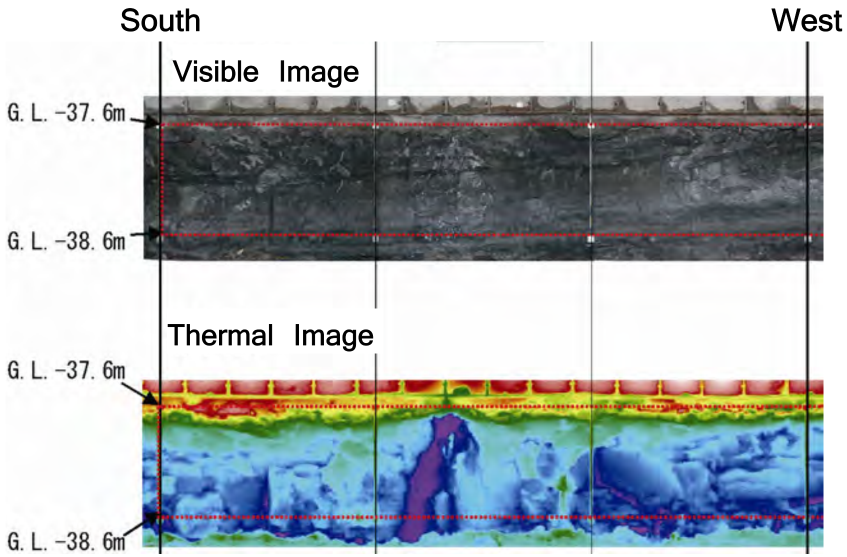
Investigation of long-term stability of the engineered barriers and the surrounding host rock

Investigations in the 2005 Fiscal Year (3/7)

Investigations in Phase 2

Shaft wall

Shaft wall observation

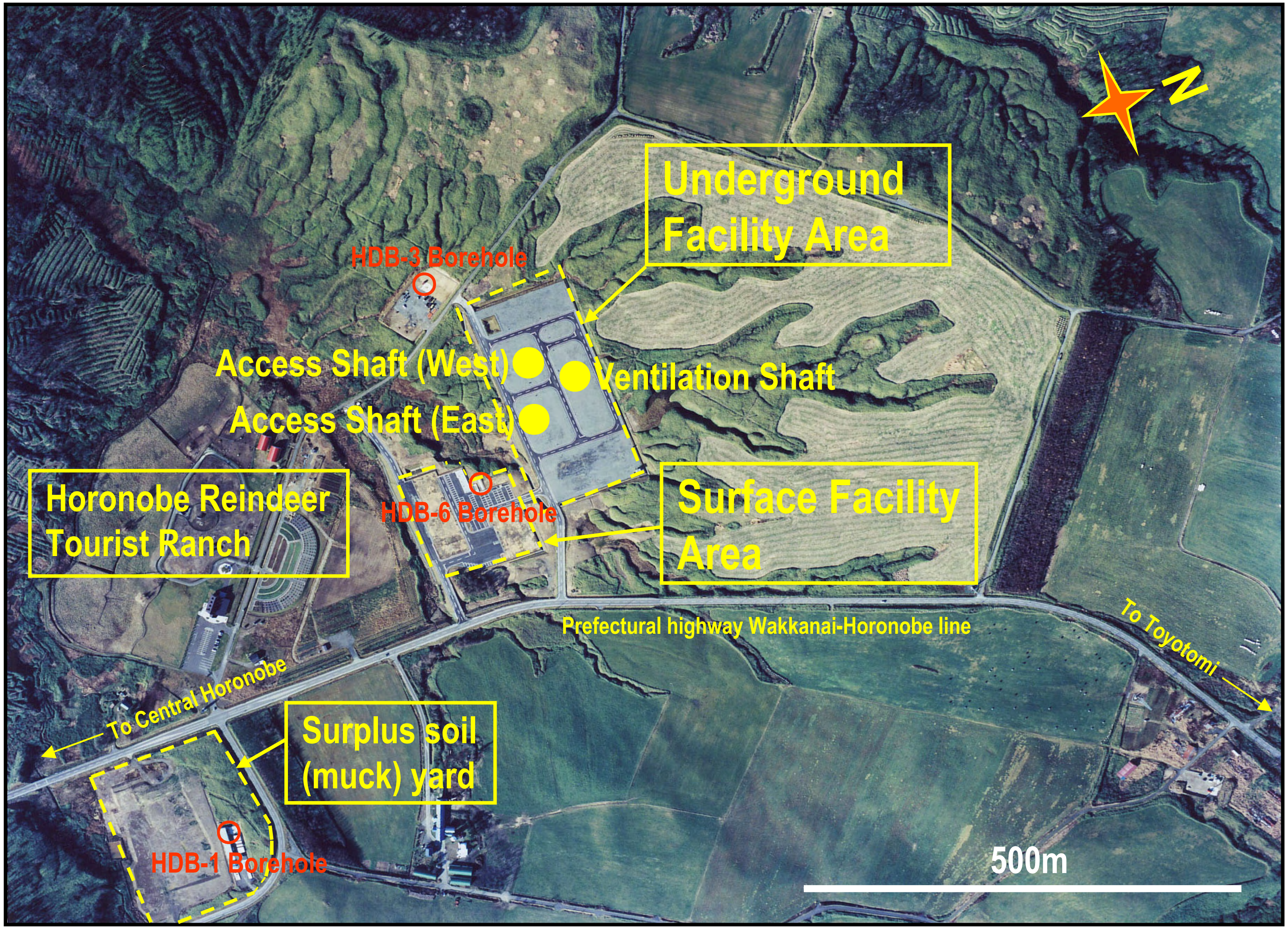


Record of shaft wall before tunnel lining

Investigation in Phase 2
in the Mizunami Underground Research Laboratory (MIU)
(geological observations)

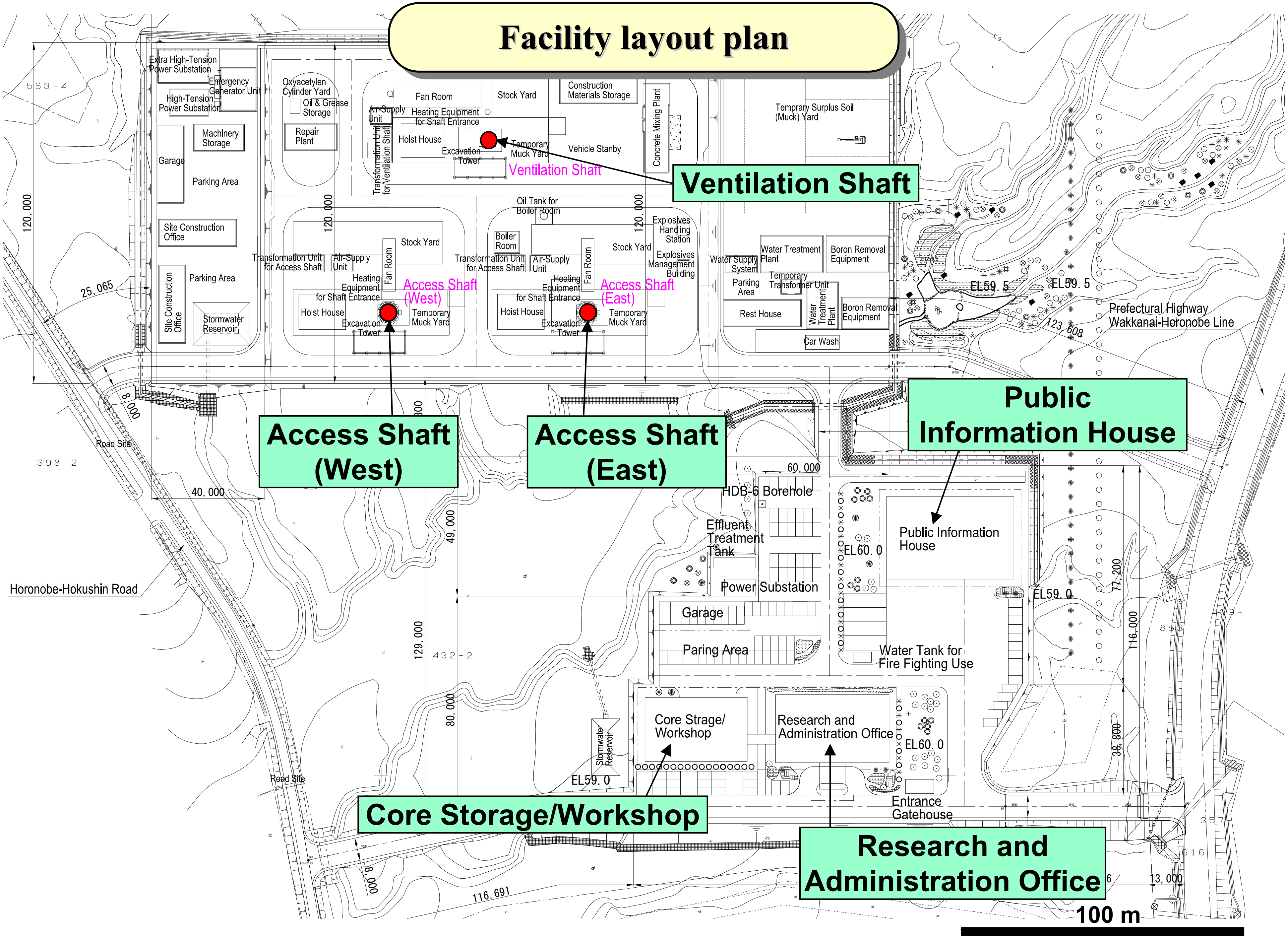
Investigations in the 2005 Fiscal Year (4/7)

Aerial photograph of the Horonobe Underground Research Laboratory



Photographed on Nov. 15, 2004

Investigations in the 2005 Fiscal Year (5/7)



Investigations in the 2005 Fiscal Year (6/7)

Projection of the surface facilities

Projection of the facilities seen from the outside

Investigations in the 2005 Fiscal Year (7/7)

Projection of the surface facility

Research and Administration Office:
Impression of the central hall seen from the inside