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Horonobe Underground Research Laboratory Project Investigation Program for the 2006 Fiscal Year (Translated Document)

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Japan Atomic Energy Agency

日本原子力研究開発機構

Horonobe Underground Research Laboratory Project
Investigation Program for the 2006 Fiscal Year
(Translated Document)

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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 Atomic Energy Agency (JAEA), is implementing the Horonobe Underground Research Laboratory Project (Horonobe URL Project) with the aim of investigation of sedimentary rock.

According to the research plan described in the Midterm Plan of JAEA, investigations of geological environments are to be carried out during the excavation of a shaft down to intermediate depth, while research and development in the areas of engineering technology and safety assessment are to be promoted by collaboration with other research organizations. The results of the R&D activities will be systematized as a "knowledge base" that supports a wide range of arguments related to the safety of geological disposal.

The Horonobe URL Project is planned to extend over a period of 20 years. The investigations will be conducted in three phases, namely "Phase 1: Surface-based investigations", "Phase 2: Construction phase" (investigations during construction of the underground facilities) and "Phase 3: Operation phase" (research in the underground facilities). This report summarizes the investigation program for the 2006 fiscal year (2006/2007), the second year of the Phase 2 investigations.

The investigations in the 2006 fiscal year are focused on the Hokushin area of Horonobe, which was selected as the area for URL construction. The main investigation region extends over approximately 3km×3km.

Construction of the underground facilities, which was initiated in the 2005 fiscal year, is ongoing and Phase 2 investigations are underway. A progress report on the surface-based investigations (Phase 1) is also being prepared.

Regarding the surface facilities, construction of the Research and Administration Facility and the Test Facility will be completed in May 2006. Construction of the Public Information House is still continuing and preparation of the exhibits has started. A preliminary design will be drawn up for the International Communication House.

Keywords: Horonobe URL Project, High-level Radioactive Waste, Geological Disposal, Geoscientific Research, Phase 2.

This document is an English translation of the JAEA R&D Report "JAEA-Research 2006-074 Horonobe Underground Research Laboratory Project -Investigation Program for the 2006 Fiscal Year".

※Cooperative Staff

幌延深地層研究計画　平成 18 年度調査研究計画
(翻訳資料)

日本原子力研究開発機構
地層処分研究開発部門幌延深地層研究ユニット
(編) 松井 裕哉、新里 忠史、山口 雄大※

(2007 年 2 月 7 日受理)

本計画は、独立行政法人日本原子力研究開発機構が堆積岩を対象に北海道幌延町で実施しているものです。

日本原子力研究開発機構の中期目標では、深地層の研究計画について、中間的な深度までの坑道掘削時の調査研究を進めるとともに、工学技術や安全評価に関する研究開発を他の研究開発機関と連携して実施し、これらの成果を地層処分の安全性に係る一連の論拠を支える知識ベースとして体系化することとしています。

本計画は、調査研究の開始から調査研究の終了まで 20 年程度の計画とし、「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こととしており、平成 18 年度はその第 2 段階の 2 年目にあたります。

平成 18 年度は、主に北進地区にある研究所設置地区（主たる調査研究の展開場所、2～3 km 四方程度）とその周辺地域において調査研究を継続します。また、地下施設の建設を継続するとともに、第 2 段階の調査研究を継続します。また、第 1 段階の研究成果の取りまとめを行い、報告書として公開します。

地上施設については、平成 17 年度に引き続き研究管理棟および試験棟（コア倉庫・ワークショップ棟を試験棟に名称変更）の建設工事を行い、平成 18 年 5 月に竣工予定です。また、PR 施設の建設工事を行うとともに展示物の製作を開始し、国際交流施設の基本設計を行います。

本報告書は、日本原子力研究開発機構 研究開発報告書「JAEA-Research 2006-074 幌延深地層研究計画 平成 18 年度調査研究計画」を英訳したものである。
幌延深地層研究センター(駐在): 〒098-3224 北海道天塩郡幌延町北進 432-2
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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 Atomic Energy Agency (JAEA; an independent administrative agency formed by a merger between the Japan Nuclear Cycle Development Institute (JNC) and the Japan Atomic Energy Research Institute (JAERI) in October 2005), is implementing the Horonobe Underground Research Laboratory Project (Horonobe URL Project).

The Horonobe URL, in which deep sedimentary rock will be investigated, is one of the underground research laboratories mentioned in the "Framework for Nuclear Energy Policy" published by the Japan Atomic Energy Commission (AEC, 2005).

In the "Framework for Nuclear Energy Policy", the following statement is described:

"Research and development institutions, led by the Japan Atomic Energy Agency, through utilization of underground research facilities, should rigorously continue to conduct scientific research on underground geology, basic research and development toward the improvement of reliability of geological disposal technology and safety assessment methods, and research and development for safety regulations. "

In the plan for meeting the midterm goal (Midterm Plan) (October 1st 2005 to March 31st 2010) drawn up by the Japan Atomic Energy Agency on the basis of the goals specified by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) and the Ministry of Economy, Trade and Industry (METI) in October 2005 (MEXT and METI, 2005), the R&D activities on processing and disposal technology for high-level waste are described as follows:

"The Agency will designate two areas, R&D on geological disposal and scientific research on underground geology. It will carry out R&D in collaboration with other R&D institution, use the outcomes of that to form a "knowledge base" that supports a variety of arguments related to the view and evaluation on ensuring the safety of geological disposal and systematize it. The outcomes of R&D during the midterm goal period will be compiled, through review of expert in Japan and abroad, as a comprehensive report and knowledge base that ensure a set level of technological quality. "

"In consideration of scientific and engineering factors depending on depth and the requirement set forth in the Specified Radioactive Waste Final Disposal Act (FY 2000 Law No. 117) (depth of 300 meters underground or more), research will be conducted when a shaft is excavated to an intermediate depth (about 500 meters underground in Mizunami City; about 300 meters underground in Horonobe-cho) ".

The Horonobe URL Project is planned to extend over a period of 20 years. The investigations will be conducted in three phases, namely "Phase 1: Surface-based investigations", "Phase 2: Construction phase" (investigations during construction of the underground facilities) and "Phase 3: Operation phase" (investigations in the underground facilities). This report summarizes the investigation program for the 2006 fiscal year (2006/2007), the second year of the Phase 2 investigations and also the second year of the Midterm Plan.

In 2006/2007, construction of the underground facilities and Phase 2 investigations continued from the previous fiscal year. The results obtained during the Phase 1 investigations are also being summarized and compiled as a comprehensive progress report.

2. Outline of the investigation program for the 2006 fiscal year

In the 2006 fiscal year, investigations will be carried out on geological structure, hydrogeology, geochemistry and rock mechanics during construction of the underground facilities. The resulting geoscientific data will be used to confirm the reliability of the models of the geological environment that were constructed based on data obtained during the Phase 1 surface-based investigations, and to improve and refine these models.

Development of investigation techniques and equipment for use in the limited space conditions of the underground facilities has been initiated. And examination on applicability of the controlled drilling techniques which were initiated in Phase 1 continuously conducted.

As part of developing techniques for monitoring the geological environment, groundwater pressure have been observed by using a long-term monitoring system installed in the boreholes drilled in Phase 1; some of the existing monitoring systems in the boreholes have also been expanded by adding data transfer units. It is also planned to install a long-term monitoring system for groundwater pressures in borehole HDB-11. For the remotely operated monitoring system, existing observation points have been maintained and the method for data analysis is being developed using data acquired up to the start of shaft excavation.

Regarding suitable engineering techniques for use in the deep underground environment, the observational construction method[1], in which data type, data acquisition method, measurement points, measurement schedule, etc. are examined during shaft and drift excavation, is being developed. Model experiments aimed at understanding the behavior of smoke-filled air in the underground facilities in the case of fire are also being carried out.

In the studies on the long-term stability of the geological environment including investigations of fault activity and analyses of rock samples, continuous measurements are being carried out using equipment such as seismographs, GPS[2] (Global Positioning System) and equipment for electromagnetic surveys[3] installed in Phase 1.

Laboratory tests using low-alkaline concrete materials are being carried out to provide input for planning in-situ tests and R&D work in Phases 2 and 3. The applicability of techniques for investigating, analyzing and assessing the geological environment are examined and the results are structured in accordance with safety assessment methodology.

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1 The observational construction method is a method for constructing underground facilities economically and safely, which involves conducting simultaneous in-situ observations of the conditions in the rock surrounding the excavated shafts and drifts. Information obtained from these observations is compared with predictions made when designing the underground facilities and is used as input for construction in the next step.

2 The Global Positioning System (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 the earth's orbit. It uses an intermediate circular orbit (ICO) satellite constellation of at least 24 satellites.

3 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.

Classification of the investigations outlined above and brief explanations are provided in Table 1. The locations of the investigations and the observation points in Horonobe-cho, including the URL site, are shown in Fig. 1.

Regarding construction of the underground facilities, excavation of the ventilation shaft is ongoing from the 2005 fiscal year and excavation of the east access shaft started in the 2006 fiscal year. A temporary surplus soil dumping area is being prepared and a drainage water treatment plant consisting of a turbid water treatment plant, a boron removal plant and a nitrogen (ammonia) removal plant is being constructed.

At the surface, construction of the Public Information House is underway and the exhibits are being prepared. A preliminary design has also been developed for the International Communication House.

For environmental monitoring, relevant parameters such as noise, vibration, water properties, flora and fauna are monitored regularly in the area around the URL site; the properties of the drainage water produced by constructing the underground facilities are also investigated.

The studies on deep sedimentary rock formations conducted as part of the Horonobe URL project are relevant to wide range of geoscientific disciplines and also contribute to various areas of academic research. JAEA therefore intends to proceed with the project by collaborating widely with experts from domestic and overseas research organizations.

3. Geoscientific research

3.1 Development of techniques for investigating the geological environment

The main objectives of the Phase 2 investigations are 1) to confirm the reliability of models of the geological environment and the applicability of investigation techniques and analysis methods developed in Phase 1, 2) to understand changes in the conditions of the geological environment and 3) to construct models of the geological environment covering an area of several tens of square meters around the underground facilities, based on data obtained during excavation. The acquisition of geoscientific data, confirmation of the reliability of the investigation techniques and the analysis methods developed in Phase1, modeling of the geological environment and development of investigation techniques/equipment for use in the underground facilities are described below.

3.1.1 Acquisition of geoscientific data

(1) Geological structure

In the Phase 1 investigations, a rough understanding was obtained of the distribution of geological formations such as the Yuchi Formation, the Koetoi Formation and the Wakkanai Formation and faults through conducting surface-based geological investigations, a range of geophysical investigations, borehole investigations and observations of drillcores. In the Phase 2 investigations, data for confirming the geological structure predicted in Phase 1 are acquired during construction of the underground facilities.

In the 2006 fiscal year, observation of outcrops at ground surface and at the shaft wall, microfossil and petrological/mineralogical analyses using rock samples from the surface and the shaft wall and observations of gas concentrations in shallow boreholes of several meters to several tens of meters deep drilled during FY 2003-2005 and from the ground surface are carried out.

(2) Hydrogeology

In the Phase 1 investigations, the distribution of hydraulic conductivity in the sedimentary rock in and around the URL area and the depth dependence of conductivity were clarified via surface and deep borehole investigations and long-term monitoring of groundwater pressures. In Phase 2, data are acquired for confirming the predictions of hydraulic conductivity distribution and groundwater pressures in the sedimentary rock.

In the 2006 fiscal year, data collections will be continued by using the meteorological observation system (precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rate) and the river flux observation system.

Groundwater level and soil moisture will also be observed by using existing and newly drilled shallow boreholes of several meters to several tens of meters deep. Based on data from these observations and the results of water chemistry analyses using river water and precipitation, groundwater flow in the shallower part of the underground environment can be roughly understood and the recharge rate from ground surface to deep underground can be estimated. Groundwater pressures are continuously monitored and any influences due to the construction of the underground facilities are confirmed.

In the underground facilities, information on hydrogeological structures including the properties of water-conducting features and the inflow rate from the surrounding rock, are acquired in parallel with excavation. Laboratory experiments using rock samples obtained in the shafts are also conducted to investigate hydraulic properties.

(3) Groundwater chemistry

Investigations of the groundwater chemistry in Phase 1 showed that groundwater in the shallower part of the underground environment has a low concentration of dissolved components, while deeper groundwater has a relatively high concentration. The shallower groundwater is formed by interaction between precipitated water and the rock, while the deeper groundwater is formed by interaction between seawater and the rock. The present groundwater chemistry is formed by mixing of these two types. In Phase 2, investigations aimed at understanding the influence of the shaft and drift excavation on the groundwater chemistry are being conducted.

In the 2006 fiscal year, water is being sampled by squeezing drillcores and by collection from the shaft wall and chemical analyses is being conducted. Water is also sampled from the existing deep boreholes such as HDB-1 - 4 and HDB-6 - 11, and from shallow boreholes, and analyzed chemically. Sampling and chemical analyses of river water and precipitation are also conducted if necessary.

(4) Rock mechanics

Laboratory tests using drillcores and in-situ tests in the deep boreholes conducted in Phase 1 showed that the mechanical properties of the sedimentary rocks in the URL area do not differ significantly from sedimentary rock of the same age distributed throughout Japan; the direction of the maximum principal stress at Horonobe is approximately east-west. In the Phase 2 investigations, the distribution of mechanical properties of the sedimentary rock measured in Phase 1 are confirmed in the underground facilities and the influence of excavation damage on the mechanical properties of the surrounding rock is investigated.

In the 2006 fiscal year, laboratory tests aimed at understanding rock deformation mechanisms on the short term and long term during and after the excavation of the underground facilities are conducted by using drillcores obtained in the Phase 1 investigations.

3.1.2 Evaluation of methodologies for investigation/analysis and for modeling of the geological environment

In the Phase 2 investigations, the consistency of models in different disciplines, such as groundwater flow and groundwater chemistry, is examined with a view to improving the reliability of the models of the geological environment developed in Phase 1. The changes in the geological environment during construction of the underground facilities are then predicted using these improved models. In addition, the applicability of the safety assessment methodology developed so far is examined using models and data relevant to the geological environment at Horonobe.

The applicability of models of the geological environment developed in Phase 1 is confirmed and they are improved based on data on the geological environment acquired during construction of the underground facilities. This allows the investigation methodologies to be systematized and models of the geological environment covering an area of several tens of square meters around the underground facilities to be developed.

(1) Geological structure model

In the 2006 fiscal year, the existing geological structure model describing the distribution and geometry of geological features, including geological formations, faults, fracture zones and folds, is being evaluated and improved if necessary, based on the results of geophysical, geological and borehole investigations conducted in Phase 1.

(2) Hydrogeological model

As a result of the hydrogeological modeling and groundwater flow analyses conducted in Phase 1, a rough understanding was obtained of the direction of groundwater flow in and around the URL area. In Phase 2, the hydrogeological model developed in Phase 1 is checked for relevance and refined. In addition, a more realistic model that considers complex phenomena such as the presence of unsaturated zones that are assumed to occur during construction of the underground facilities is being constructed.

The hydrogeological model covering the URL and the surrounding area is being improved. Using this model, predictions are made of the inflow from the surrounding rock into the underground facilities and the changes in groundwater pressure during construction of the underground facilities. In addition, groundwater flow analyses considering different water densities, including fresh water, saline water and dissolved gas, are being conducted; the consistency of the models in the different disciplines is also examined.

In order to evaluate the reliability of the hydrogeological model developed based on data obtained from surface-based investigations and groundwater flow analyses, the predicted results are compared with observed data on inflow rate from the surrounding rock into the underground facilities, measured groundwater pressures in the deep boreholes, groundwater level in the shallow boreholes, etc.. A hydrogeological model on surrounding of the underground facilities is also being developed based on data acquired during the construction of the underground facilities.

(3) Geochemical groundwater model

In Phase 1, groundwater chemistry in the URL area and its surrounding was estimated based on the results of investigations of geochemical properties, including chemical analyses of groundwater sampled by squeezing drillcores and directly from boreholes; the mineralogical and chemical composition of the drillcores was also analyzed. The changes in geochemical groundwater properties caused by the construction of the underground facilities were predicted. In the Phase 2 investigations, the reliability of these predictions and the methods developed in Phase 1 are evaluated.

The reliability of the geochemical model is being confirmed and improvements will be made if necessary, using the data acquired in investigations conducted in the underground facilities.

(4) Rock mechanical model

In the Phase 1 investigations, a rock mechanical model taking into account the properties of the sedimentary rock in and around the URL area and the distribution of the maximum principal stress acting on the rock was developed based on the results of laboratory tests using drillcores and of in-situ tests conducted in the boreholes. The deformation and change in stress in the surrounding rock during construction of the underground facilities were then predicted. In Phase 2, the mechanical model developed in Phase 1 will be evaluated and refined. In addition, a model which is able to reproduce the changes in the properties of the surrounding rock is being developed.

In the 2006 fiscal year, the generation mechanism and the extent of changes in the properties of surrounding rock during the excavation are studied in detail based on data obtained in Phase 1. A modeling method for analyzing the long-term deformation of the surrounding rock following the excavation is also being examined.

3.1.3 Development of investigation techniques and equipment

In the Phase 1 investigations, the applicability of existing investigation techniques, including borehole drilling technology, etc., applied at ground surface and in boreholes was confirmed. The investigation techniques were then further developed taking the characteristics of the sedimentary rock and the groundwater in the underground environment at Horonobe into consideration.

In the 2006 fiscal year, the applicability of the investigation techniques used in Phase 1 is being evaluated and the results are being summarized. As part of the continuing development of surface-based investigation techniques, drilling methods capable of controlling the angle and direction of boreholes (controlled drilling) are being examined. Controlled drilling towards the Omagari Fault has also been initiated in the Kami-Horonobe area.

Development of the investigation techniques and equipment required for data acquisition in a range of disciplines using the underground facilities has been initiated. Concerning hydrogeology, equipment for measuring the hydraulic conductivity in a borehole drilled from the drift wall into the surrounding rock is being designed and manufactured. For geochemistry, in-situ equipment capable of monitoring the pH, redox potential (Eh), etc. of groundwater is also being designed and manufactured. In rock mechanics, optical displacement meters for stable measurement of the displacement of the sedimentary rock on the long term during shaft and drift excavation are being developed.

A system for monitoring changes in the geological environment of the URL area during construction of the underground facilities is also being developed. A system capable of continuously monitoring changes in specific resistivity is being installed and measurements are made by allocating measurement points along the lines connecting existing boreholes.

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

3.2.1 Development of monitoring techniques in boreholes

In Phase 1, long-term monitoring systems for groundwater pressure/geochemistry were installed in the boreholes. The groundwater conditions before construction of the underground facilities were then observed and the performance of these monitoring systems was evaluated. In Phase 2, the stability of these systems is being confirmed and data on changes in the geological environment due to construction of the underground facilities are being acquired.

In the 2006 fiscal year, observations of groundwater pressure/geochemistry are ongoing using long-term monitoring systems and a technique for monitoring influences originating from various investigation activities and from construction of the underground facilities are being developed.

Parts of the monitoring systems installed in Phase 1 are being upgraded by adding data transfer units; work on installing the long-term monitoring system in HDB-11 is ongoing from the previous fiscal year and monitoring of groundwater pressure, etc. has been initiated. Methods for processing and analysis of the monitoring data are being developed to provide an accurate understanding of the changes in groundwater pressures.

Several boreholes around 30 m in depth have been drilled around the shafts, high-precision tiltmeters and pore pressure meters have been installed in the boreholes and measurements initiated.

3.2.2 Development of a remotely operated monitoring system

In Phase 1, a remotely operated monitoring system using seismic and electromagnetic waves was installed and the conditions of the geological environment prior to construction of the underground facilities were observed. In Phase 2, the relevance of this technology for monitoring changes in the conditions of the geological environment during construction of the underground facilities is being examined. Monitoring at existing observation points is continuing. In order to acquire detailed data in the vicinity of the underground facilities, short-term observations are conducted at the URL site.

3.3 Development of engineering techniques for use in the deep underground environment

In Phase 1, the underground facilities were designed based on data acquired during surface-based investigations. In Phase 2, the applicability of engineering techniques for construction of the underground facilities is evaluated and the techniques are being systematized. Specifically, data relevant to changes in the geological environment, stress development in cavity support systems, etc. are measured continuously to allow the design of the underground facilities and the construction techniques to be optimized in the next step.

The so-called observational construction method is now being developed considering the data to be acquired during construction of the underground facilities, data acquisition methods, methods for evaluating the reliability of the design using the data and methods for reflecting the information obtained in the previous step in subsequent steps. At the same time, model experiments for understanding the behavior of smoke-filled air in the underground facilities in the case of fire are being conducted.

3.4 Studies on the long-term stability of the geological environment

3.4.1 Studies on long-term changes in the geological environment

In Phase 1, fault activity, folding and sea-level changes were selected as the natural phenomena assumed to have influenced the present geological environment at Horonobe, based on the evaluation of surface geological investigations, analyses of rock samples, GPS measurements and seismological observations. The evolution of the geological environment from the Neogene to the Quaternary was then reconstructed. In Phase 2, a method capable of modeling the long-term changes in the geological environment from the Neogene to the Quaternary is being developed by combining groundwater flow analyses and the reconstructed evolution of the geological environment.

Investigations of topography, deformation of geological formations and fault activity and analyses of microfossils and petrology/mineralogy using rock samples obtained from outcrops are being conducted. Information on crustal movements and climate changes from the Neogene to the Quaternary in and around Horonobe are being collected and classified. In addition, GPS and electromagnetic measurements are continuing and the extent of the crustal movements is being analyzed.

3.4.2 Seismological studies

In the Phase 1 investigations, data were obtained on seismological activity in the Horonobe. In Phase 2, these investigations are continuing and the influence of seismological activity on the geological environment is studied by combining data on the geological environment obtained at the surface and in the underground facilities.

In the 2006 fiscal year, observations were made of micro-earthquakes in the Horonobe area and its surroundings using seismographs installed at ground surface and at the bottom of a 138 m-deep borehole. Based on these data, hypocenter distribution and geological structure in the deep underground are studied. In addition, information on past seismic activity in the Horonobe area is being collected and classified.

4. Research and development on geological disposal technology

4.1 Improving the reliability of disposal technologies

4.1.1 Verification of the engineered barrier technology

In Phase 1, basic plans were drawn up for in-situ tests aimed at verifying the engineered barrier technologies to be applied in Phase 2. In Phase 2, detailed in-situ test plans are being examined and in-situ tests on, for example, the workability of low-alkaline concrete materials are being carried out.

Regarding materials for tunnel support and tunnel sealing systems, laboratory tests on the workability of materials such as low-alkaline concrete are being conducted in the present fiscal year, to provide input for detailed planning of in-situ tests to be performed in the underground facilities in Phases 2 and 3.

4.1.2 Confirming the applicability of EBS design methods

In Phase 1, the applicability of the design methods for the engineered barrier system proposed in JNC's second progress report on research and development on the geological disposal of HLW in Japan was evaluated and the methods were improved. In Phase 2, these improved design methods are applied to determine the specifications of in-situ tests.

In the 2006 fiscal year, the long-term behavior of the engineered barrier system and the surrounding rock are being studied and the design conditions are classified based on data on the geological environment obtained in Phase 1 and data from laboratory tests using drillcores and groundwater sampled from the borehole investigations conducted up to the 2005 fiscal year.

4.2 Enhancement of safety assessment methodologies

4.2.1 Confirming the applicability of safety assessment methodologies

In Phase 1, experimental methods for acquiring mass transport parameters using drillcores obtained during borehole investigations were examined and analyses of mass transport in sedimentary rock were conducted. In Phase 2, mass transport analyses on different scales, such as the regional and site scale, are being conducted and the knowledge obtained in the processes of modeling and analysis is being structured and integrated. The applicability of existing safety assessment methodologies is then examined.

In the 2006 fiscal year, the characteristics of the geological environment and the parameters influencing groundwater flow and mass transport are examined based on the results of mass transport analyses and uncertainty analyses on a regional scale of 15 km×30 km, including the URL area. Based on the results of the regional scale analysis, modeling of mass transport on the site scale of 10 km^2 (including the URL area) is conducted.

5. Construction of the underground facilities

In the 2006 fiscal year, the ventilation shaft is still being excavated and excavation of the east access shaft has been initiated. In addition, preparation of land for a temporary surplus soil (muck) dumping yard and construction of a drainage water treatment facility with a turbid water treatment plant, a boron removal plant and a nitrogen (ammonia) removal plant, with construction of drainage lines, are ongoing.

Temporary facilities such as an excavation tower, a scaffold, an explosive storage, a concrete mixing plant and an extra high-tension power substation necessary for shaft excavation are being constructed.

At the beginning of shaft excavation, the foundations for the excavation tower superstructure[4] were laid and substructure work was then carried out. As an auxiliary facility to the ventilation shaft, a fan shaft is also being excavated. Tunnel support[5] is installed immediately after excavation and the stability of the surrounding rock is thus preserved. The type of support is selected taking into account information such as the mechanical properties of the surrounding rock. In addition, since flammable gas containing methane as a major component generally exists in the sedimentary rock of Japan and has also been detected in and around the URL area in Horonobe, shaft excavation is carried out using explosion-proof excavation apparatus and with monitoring of the gas concentrations by way of safety management.

Surplus soil (muck) produced by shaft excavation is conveyed from the shaft to ground surface by a steel bucket called a kibble. The muck conveyed to the surface is stored in a temporary dumping yard which is covered by impermeable asphalt-saturated sheeting and is finally transported to the permanent dumping yard after the start of operation. The surplus soil yard will consist of a double liner sheet structure based on an impermeable containment system pursuant to the Soil Contamination Countermeasures Law; the aim is to prevent release of natural toxic materials contained in muck and water.

The drainage water produced in the underground facilities is released to the Teshio River by drainage pipes after appropriate treatment. Until construction of the drainage treatment facility and the drainage pipes has been completed, the drainage produced during shaft excavation is treated as industrial waste.

6. Construction of the surface facilities

Construction of the Research and Administration Facility and Test Facility continued from the 2005 fiscal year, and is completed in May 2006. In addition, construction of a Public Information House is also ongoing and exhibits are being prepared. Preliminary design of an International Communication House is also underway.

7. Environmental monitoring

7.1 Monitoring of noise, vibration, water property, flora and fauna

Monitoring of noise, vibration, water property, flora and fauna is performed regularly in the area around

[4] The superstructure is made of reinforced concrete at the upper part of the shaft entrance. This structure is used as a foundation for the excavation tower and as an entrance for persons, tunneling materials, etc.
[5] Tunnel support is installed to preserve the stability of the surrounding rock and the underground voids of tunnels. The tunnel support system usually consists of rock bolts, steel arch supports and shotcrete.

the URL site.

7.2 Monitoring the construction of the underground facilities

In the 2006 fiscal year, monitoring of water properties in the construction area, the underground facilities and their surroundings, the surplus soil (muck) yard and the Teshio River (outlet of the drainage lines) is being carried out.

The items for analysis described in the Water Pollution Control Law are used as the basis for monitoring water properties. Drainage produced from construction of the underground facilities, treated water, seepage water from the surplus soil (muck) yard and shallow groundwater and river water close to the surplus soil (muck) yard are monitored.

8. Collaboration with other research organizations

The geoscientific studies looking at the deep underground environment in sedimentary rock that are being conducted as part of the Horonobe URL Project are relevant to wide range of areas in the geosciences and also contribute to academic research. JAEA is therefore proceeding with the project through collaboration with experts from domestic and overseas research organizations, including Hokkaido University and others.

8.1 Collaboration with domestic research organizations

8.1.1 Collaboration with universities

- Hokkaido University:
  - Study on transport pathways of dissolved gases and materials in compacted bentonite[6]
- Saitama University:
  - Study on groundwater flow modeling
- Tsukuba University:
  - Geochemical study on rocks, minerals and groundwater
- Tokyo University:
  - Development of technology for evaluating hydrogeological models using stable isotope ratios of chlorine
- Shizuoka University:
  - Development of a remotely operated monitoring system
- Kyoto University:
  - Study on analysis of AE[7](Acoustic Emission) properties of sedimentary rock using drillcores and in-situ measurement methods
  - Study on groundwater flow considering the influences of fracture zones
- Yamaguchi University:

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[6] Compacted bentonite is formed by compacting and solidifying bentonite clay powder. This is a candidate for the buffer material that forms part of the engineered barrier system (EBS).

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

- Study on in-situ measurement methods for dissolved methane gas

8.1.2 Collaboration with other research organizations

- Central Research Institute of Electric Power Industry (CRIEPI)[8]:
  - Study for evaluating environmental characteristics relevant to geology and groundwater (including development of controlled drilling)
- Radioactive Waste Management Funding and Research Center (RWMC)[9]:
  - Study on applicability of high-accuracy geophysical investigation technologies
  - Study on applicability of investigation technologies for the geological environment
- Institute for Research and Innovation (IRI)[10]:
  - Study on enhancing the reliability of models relevant to groundwater chemistry and flow
  - Study on the impact of microbial activity on geological disposal
- Horonobe Research Institute for the Subsurface Environment (H-RISE)[11]:
  - Study on characteristics of sedimentary rock
- Geological Survey of Hokkaido[12]:
  - Study on reconstruction of the paleo-environment
- Shimizu Corporation:
  - Study on modeling technology for the geological environment

8.2 Collaboration with overseas research organizations

- Nagra[13] (Switzerland):
  - Planning of investigations in the URL project and review of annual progress
- Mont Terri Project[14] (Switzerland):
  - Participation in the test for evaluating the geochemical characteristics of pore water in impermeable sedimentary rock

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[8] CRIEPI is a research institute specializing in electric power technology. As part of its activities, research and development on geological disposal of high-level radioactive waste is carried out.

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

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

[11] 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.

[12] The Geological Survey of Hokkaido was established to conduct research on geology and underground resources in Hokkaido. Currently, 1) research on development, utilization and management of underground resources, 2) research on land conservation and preservation of the underground environment, 3) research on analysis and prevention of geological disasters and 4) improvement of geological information management are its main activities.

[13] The National Cooperative for the Disposal of Radioactive Waste (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)

[14] The Mont Terri Project is an international URL project for in-situ testing in sedimentary rock relevant to research and development on geological disposal. Currently, 11 organizations from six countries, including JAEA, are participating in this project and various types of in-situ tests relevant to geological disposal have been carried out in the tunnel system in the Jura mountains of Switzerland.

In addition to the existing collaborative studies mentioned above, cooperation with Advanced Industrial Science and Technology (AIST)[15], ANDRA[16] and other organizations is also being considered. The facilities and study areas used in the Horonobe URL Project are open to domestic and overseas research organizations in the field of geological disposal.

[15] AIST was reorganized in 2001 from the former Agency of Industrial Science and Technology (AIST) administered by Ministry of International Trade and Industry (MITI). AIST is the largest research institute in Japan covering a wide range of disciplines in the industrial technologies and various types of technology developments are carried out. The current disciplines covered by AIST are mainly classified into life sciences, telecommunications/electronics, nanotechnology/materials/manufacturing/, environment/energy, geology and standards/measurements.

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

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Table 1 Summary of main investigations conducted in the 2006 fiscal year

Investigations		Content	Place
Development of techniques for investigate the geological environment	Geological structure	Outcrop observations, core sampling, microfossils and petrological/mineralogical analyses of core samples Measurements of methane and carbon dioxide	Hokushin area, Kami-Horonobe area, shaft (and drift), shallow boreholes (Hokushin, Kaishin) etc.
	Hydrogeology	Meteorological monitoring (precipitation, temperature, humidity, wind direction & velocity, evaporation), river flux monitoring, groundwater level/soil moisture observation, Monitoring of groundwater pressure Rock permeability test (laboratory), drilling shallow boreholes	Meteorological observation station (Hokushin, Horonobe, Kami-Toikan, Toikanbetsu), Hokushin evapotranspiration observation tower, P-3 - P-5, URL site, shallow boreholes, HDB-1 - 4, HDB-6 - 11
	Groundwater chemistry	Sump water from shaft wall, borehole water, river water/precipitation, water sampling by squeezing drillcores and chemical analyses	Shaft (and drift), HDB-1 - 4, HDB-6 - 11, P-3 - P-5
	Rock mechanics	Laboratory tests for understanding rock deformation mechanism	(No field work)
	Development of investigation techniques and equipments	Examination of the controlled drilling techniques, resistivity monitoring from ground surface, development and trial manufacture of the investigation tools used in the boreholes in the URL.	URL site, Kami-Horonobe, Hokushin
Development of techniques for long-term monitoring of the geological environment	Development of monitoring techniques in the boreholes	Groundwater pressure observations, installation of a long-term monitoring system (in borehole HDB-11), installation of data transfer units, installation of high-precision tiltmeters and pore pressure meter	HDB-1 - 4, HDB-6 - 11, URL site
	Development of a remotely operated monitoring system	Constant/short-term observations of geological structure/environment, maintenance of existing observation system	URL site, HDB-3,4,5,8 area, Receiving point-Z
Development of engineering techniques for use in the deep underground environment		Development of observational construction method, model experiments for understanding the behavior of smoke-filled air in the underground facilities in case of fire	(No field work)
Studies on the long-term stability of the geological environment	Studies on long-term changes in the geological environment	Outcrop observation, microfossils and petrological/mineralogical analyses of core samples, GPS and electromagnetic measurements	Hokushin, Kami-Horonobe, HDB-1,2,5 area, Horonobe Park observation point, Kami-Toikan observation point
	Seismological studies	Observations of micro-earthquakes using seismographs	HDB-2, 5 area, Naka-Toikan observation point, Hokuseien observation point
Research and development on geological disposal technologies	Improving the reliability of disposal techniques	Development of low-alkaline concrete, classification of data for application of EBS design method	(No field work)
	Enhancement of safety assessment methodologies	Examination of characteristics of the geological environment and parameter types/accuracies based on the results of the analyses of mass transport on the regional scales, modeling of mass transport	(No field work)
Construction of the underground facilities		Excavation of ventilation/east shaft, construction of (temporary) surplus soil (muck) yard, construction of drainage treatment facility, construction of drainage lines	URL site, etc.
Construction of the surface facilities		Construction of Research and Administration Facility and Test Facility, Construction of Public Information House and preparation of the exhibits, Design of international communication house	URL site
Environmental monitoring		Monitoring of noise, vibration, water property, flora and fauna Monitoring of drainage water from construction of URL facilities	URL site, Teshio River, Shimizu River

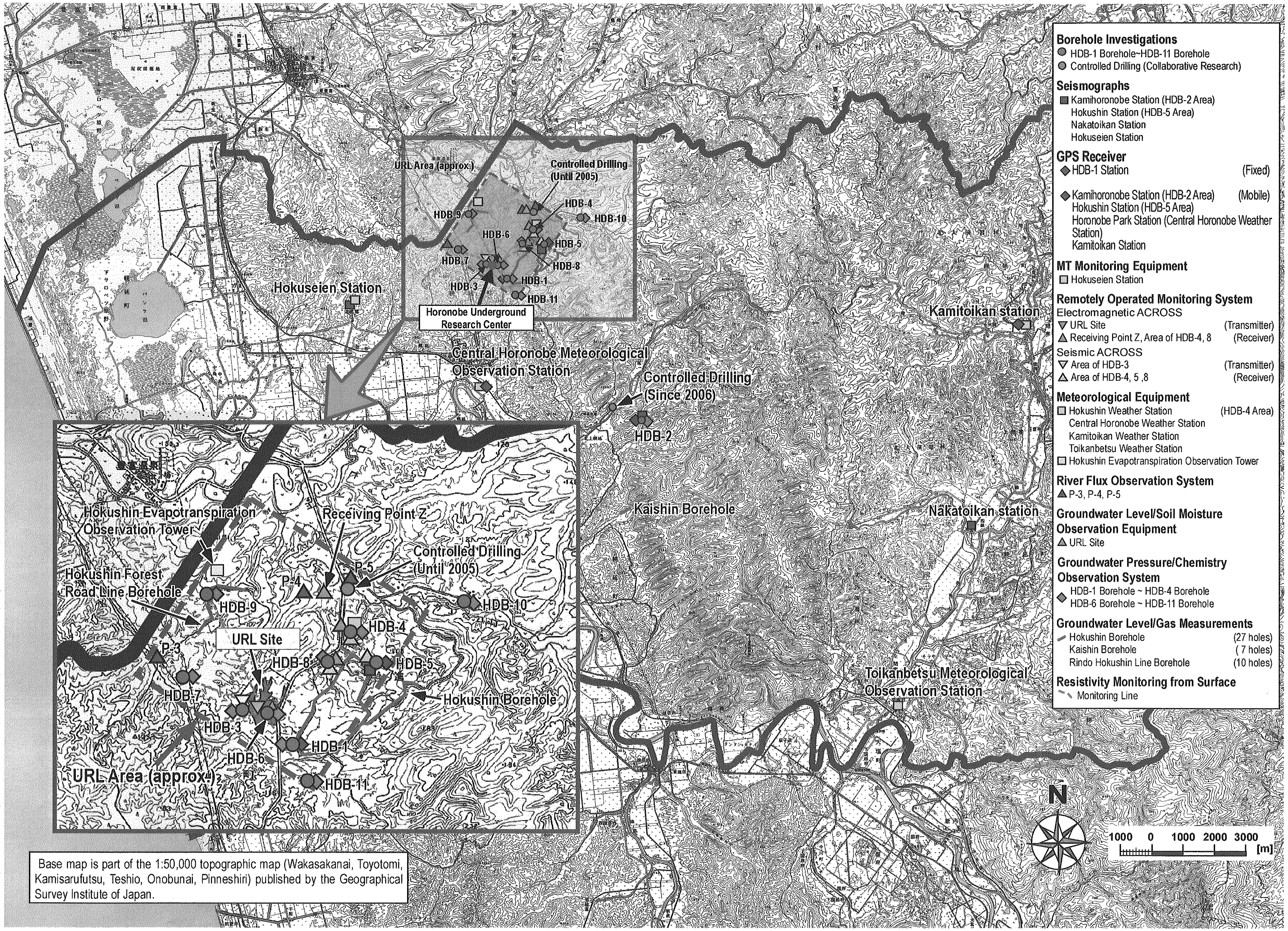

Fig.1 Location of investigations

Appendix

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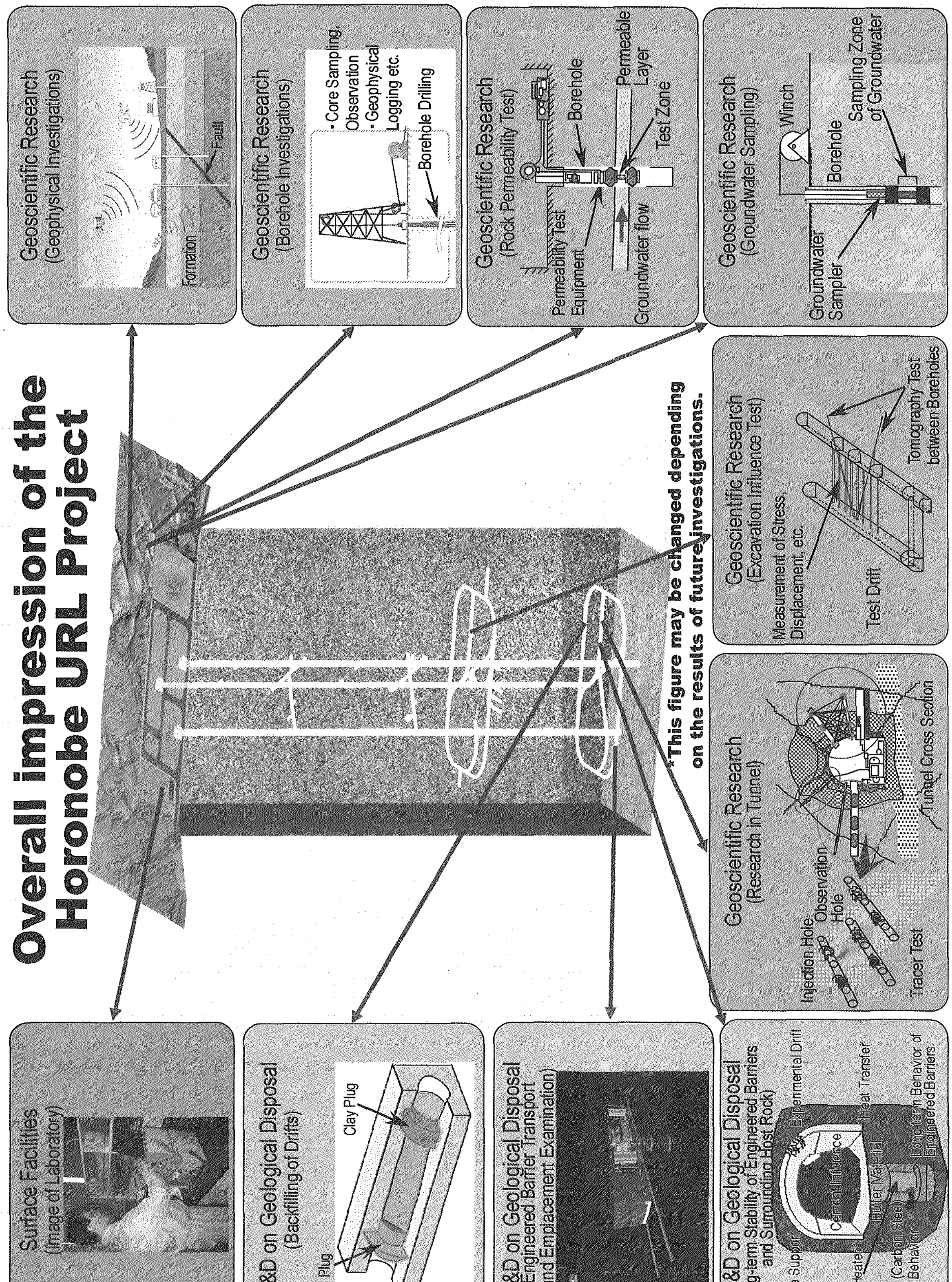
Investigation schedule (2005 Fiscal Year - 2006 Fiscal Year)

Fiscal Year: 2005 | 2006 | 2007 | 2008 | 2009

Investigation Phase: Surface-based Investigation Phase; Summary of the "Surface-based Investigation Phase"; Construction Phase; ▼ Establishment of Japan Atomic Energy Agency; "A plan for meeting the midterm goal (Midterm Plan)" (METI and MEXT, October 2005; Period from October 1st, 2005 to March 31st, 2010)

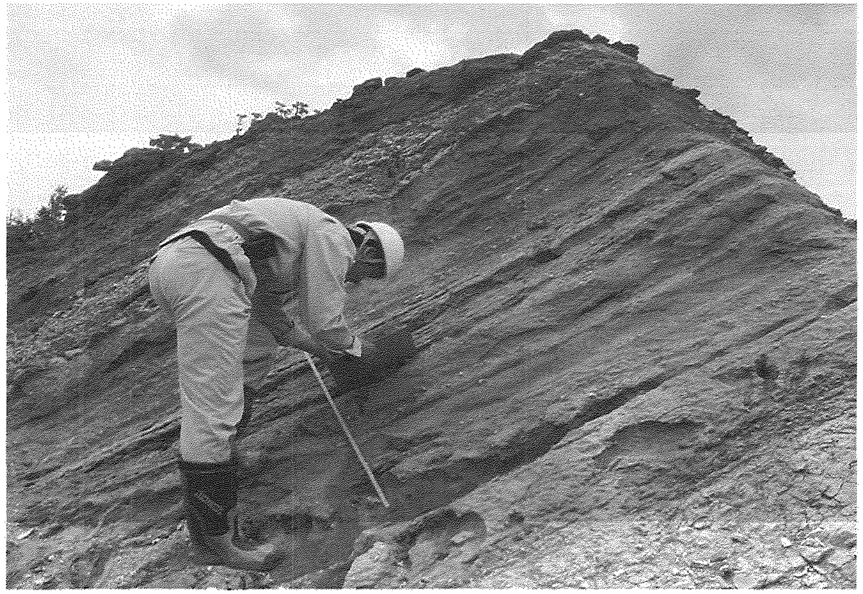
Item	Content	
3. Geoscientific research		
3.1 Development of techniques for investigating the geological environment		
3.1.1 Acquisition of geoscientific data		
(1) Geological structure	•Core sampling/analysis from underground facilities, ground surface and drillcores	
(2) Hydrogeology	•Groundwater monitoring, surface hydrogeological investigations and drillcores	Data acquisition during construction of the underground facilities / comparison with the data obtained before construction
	•Measurements of groundwater inflow in underground facilities •Hydrogeological investigations in boreholes (permeability test, groundwater pressure, etc.)	Data acquisition during construction of the underground facilities
(3) Groundwater chemistry	•Water sampling/analysis from existing deep boreholes	
	•Water sampling/analysis from the shaft/drift wall •Water sampling/analysis from boreholes drilled in the underground facilities	
(4) Rock mechanics	•Laboratory tests using drillcores from the deep boreholes	
	•Rock mechanical investigations using drillcores from boreholes drilled in the underground facilities	
3.1.2 Evaluation of methodologies for investigation/analysis and for modeling of the geological environment		
(1) Geological structure model	•Applicability confirmation/improvement of the geological structure model for an area of several hundred meters to several square kilometers •Modeling the geological structure over an area of several tens of square meters	
(2) Hydrogeological model	•Analyses for predicting the inflow and the distribution of the groundwater pressure at/around the underground facilities •Applicability confirmation/improvement of the hydrogeological model for an area of several hundred meters to several square kilometers •Modeling the hydrogeology over an area of several tens of square meters	Predictive analysis / Comparison with actual measurements/Modeling and Updating
(3) Geochemical model of groundwater	•Applicability confirmation/improvement of the geochemical model for an area of several hundred meters to several square kilometers •Modeling the geochemistry over an area of several tens of square meters	
(4) Rock mechanical model	•Applicability confirmation/improvement of the rock mechanical model for an area of several hundred square meters •Modeling in time dependence deformation	
3.1.3 Development of investigation techniques and equipment	•Development of various investigation techniques	Development and improvement of the investigation equipment; Application Test / Practical Use
	•Development of monitoring system for geological environment changes by ground geophysical survey during construction of the underground facilities	Installation of the observation system; Continuous monitoring / Data analyses (Annual)
3.2 Development of techniques for long-term monitoring of the geological environment		
3.2.1 Development of monitoring techniques in boreholes	•Maintenance of long-term monitoring system installed in the existing boreholes	Maintenance of monitoring equipment / Management of acquired data; Data analysis
3.2.2 Development of a remotely operated monitoring system	•Monitoring by remotely operated system using seismic and electromagnetic waves, and examination of applicability	Maintenance of observation system; Continuous monitoring / Data analyses
3.3 Development of engineering techniques for use in the deep underground environment	•Validation of design based on various data measured during construction of the underground facilities, examination of observational construction method for sedimentary soft rock, etc.	Observational construction method; Data acquisition during construction of the underground facilities / Relevance evaluation of the preliminary design
3.4 Study on long-term stability of the geological environment		
3.4.1 Study on long-term changes in the geological environment	•Sampling and analysis at ground surface and in the underground facilities, history of natural phenomena (such as fault activity, erosion, ridges, troughs, climate change, eustasy, etc.) and study of effects on the geological environment •Verification of the geological environment modeling methods considered history of natural phenomena and long-term changes of the geological environment	Planning; Sampling and analysis, history of natural processes and events, effects on geological environment; Modeling and updating of geological environment considered long-term changes; Verification of methods for evaluating effects of natural phenomena
3.4.2 Seismological studies	•Understanding earthquake activity using seismometers on the ground surface Understanding of effect of earthquake activity and tectonics on groundwater •Understanding earthquake activity using seismometers in the underground facilities Understanding of effect of earthquake activity and tectonics on groundwater	Earthquake observation and GPS observation; Planning; Installation of seismometers
4. Research and development on geological disposal technology		
4.1 Improving reliability of disposal techniques		
4.1.1 Verification of engineered barrier technology	•Studies on workability of low-alkaline concrete, feasibility of engineered barrier system, backfilling of drifts, etc.	Understanding of basic properties in laboratory tests; Planning for in-situ tests; Low-alkaline concrete material test; Monitoring
4.1.2 Applicability confirmation of EBS design methods	•Validity evaluation, Updating and enhancement of the design methods for the engineered barrier system based on "Summary in 2005FY"	preliminary survey; Planning for in-situ tests
4.2 Enhancement of safety assessment methodologies		
4.2.1 Applicability confirmation of safety assessment methodologies	•Application of safety assessment methodologies for in-situ geological environment and advancement of methodologies based on this result	Modeling and analysis of mass transport on site scale; Modeling and analysis of mass transport on regional scale
5. Construction of the underground facilities		
- Underground Facilities	•Construction Ventilation shaft, Access shaft (East and West), 140m drift and 280m drift	Ventilation Shaft (including Fan Shaft): Shaft excavation and construction of temporary facilities; Access Shaft (East) / Access Shaft (West): Shaft excavation and construction of temporary facilities; 140m-Drift; 280m-Drift
- Auxiliary facilities (Effluent treatment facility, Surplus soil (muck) yard, etc.)	•Construction/Operation Drainage Line, Effluent Treatment Facility and Surplus Soil (Muck) Yard	Construction of the Drainage Line; Discharge to Drainage Line; Effluent Treatment Facility: Construction of Effluent Treatment Facility; End of the first stage construction; Surplus Soil (Muck) Yard: Haulage Road; First stage; Transport to Surplus Soil (Muck) Yard; Second Stage Construction
6. Construction of the surface facilities		
- Research and Administration Facility/Test Facility	•Construction	Construction (Due for completion in May 2006)
- Public Information House	•Construction of Public Information House •Fabrication and setting of the exhibits	Construction; Preparation for opening; in-service; Execution design; Fabrication of the exhibits
- International Communication House	•Design and construction of International Communication House	Conceptual design; Preliminary design; Execution design; Construction
7. Environmental monitoring		
7.1 Monitoring of noise, vibration, water property, flora and fauna - Water properties -Plants and animals - Noise and vibration	•Regular analysis of river water every three months •Regular ecological survey in spring, summer and winter (including rare species) •Regular noise monitoring every three months (around the URL site)	Monitoring
7.2 Monitoring of construction of the underground facilities - Drainage water, seepage water from surplus soil (muck) yard and surrounding water quality survey - Teshio River		Background measurements; Monitoring Background measurements; Monitoring
8. Collaboration with other research organization		
8.1 Collaboration with domestic research organizations		
8.1.1 Collaboration with universities	•Research cooperation	Advanced basic research, collaborative research
8.1.2 Collaboration with other research organizations	•Research cooperation on the basis of agreements, contracts, etc.	Collaborative research
8.2 Collaboration with overseas research organizations	•Research cooperation on the basis of agreements, contracts, etc.	Collaborative research


Overall impression of the Horonobe URL Project
*This figure may be changed depending on the results of future investigations.
Geoscientific Research (Geophysical Investigations)
Formation
Fault
Geoscientific Research (Borehole Investigations)
・Core Sampling, Observation
・Geophysical Logging etc.
Borehole Drilling
Geoscientific Research (Rock Permeability Test)
Permeability Test Equipment
Borehole
Permeable Layer
Test Zone
Groundwater flow
Geoscientific Research (Groundwater Sampling)
Winch
Borehole
Sampling Zone of Groundwater
Groundwater Sampler
Geoscientific Research (Excavation Influence Test)
Measurement of Stress, Displacement, etc.
Test Drift
Tomography Test between Boreholes
Geoscientific Research (Research in Tunnel)
Injection Hole
Observation Hole
Tracer Test
Tunnel Cross Section
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 and Emplacement Examination)
R&D on Geological Disposal (Long-term Stability of Engineered Barriers and Surrounding Host Rock)
Concrete Support
Experimental Drift
Cement Influence
Buffer Material
Heat Transfer
Electric Heater
Overpack (Carbon Steel) Corrosion Behavior
Long-term Behavior of Engineered Barriers

Investigations in the 2006 Fiscal Year (1/17)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: geological structure)

To investigate geological structures, observation of outcrops at ground surface and at the shaft wall, microfossil and petrological/mineralogical analyses using rock samples from the surface and the shaft wall and observations of gas concentrations in shallow boreholes of several meters to several tens of meters deep drilled during FY 2003-2005 and from the ground surface are carried out.


Outcrop observation

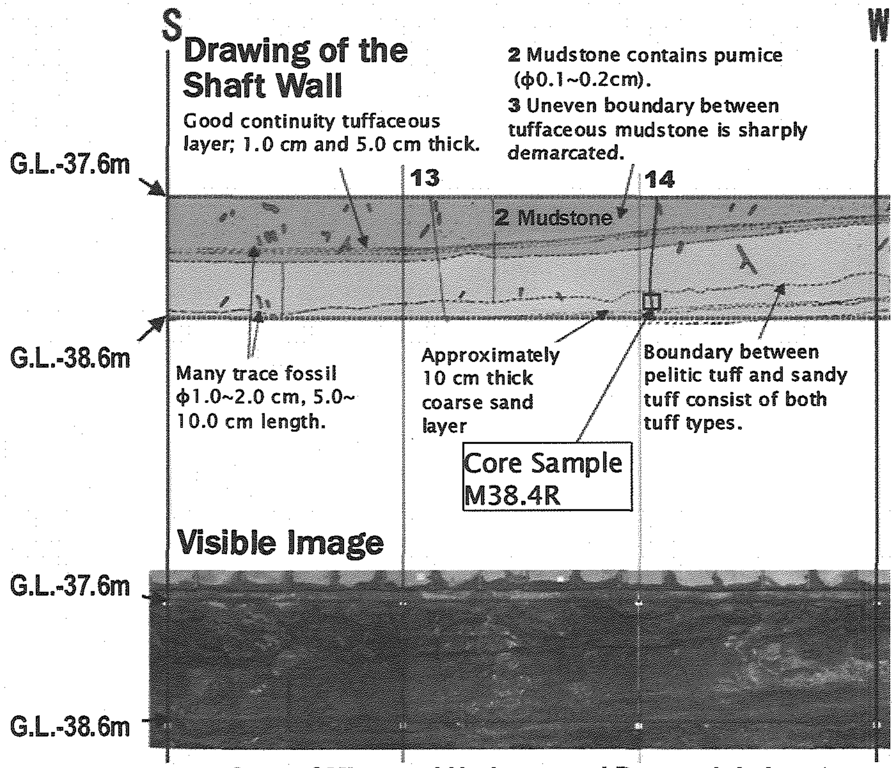

Observation of gas concentration

Investigations in the 2006 Fiscal Year (2/17)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: geological structure)

Photographed at Mizunami Underground Research Laboratory

Shaft wall observation



Case of Mizunami Underground Research Laboratory

Record of shaft wall before applying tunnel lining

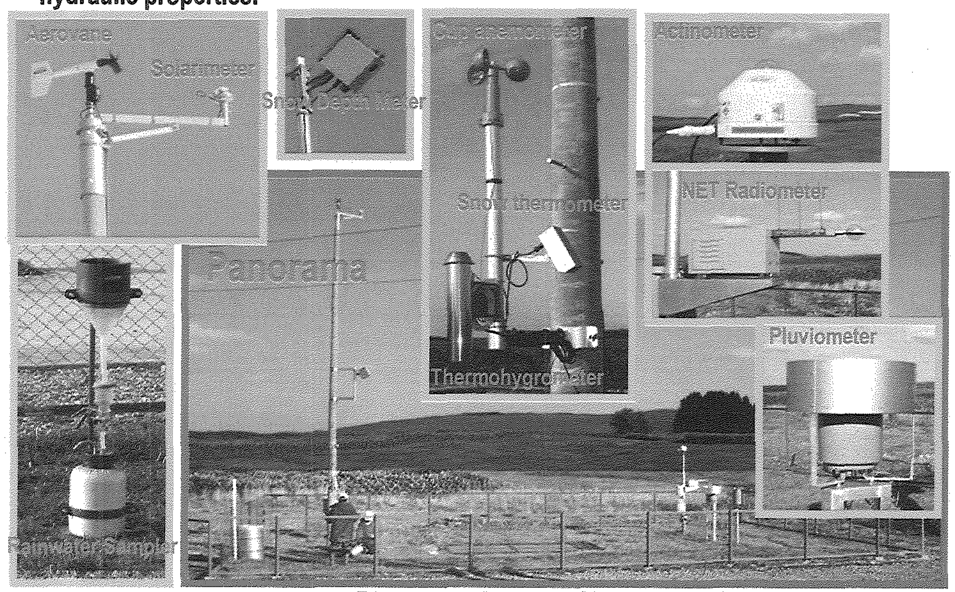
Investigations in the 2006 Fiscal Year (3/17)

Development of techniques for investigating the geological environment (acquisition of geoscientific data: hydrogeology)

Data collections using the meteorological observation system (precipitation, temperature, humidity, wind velocity, wind direction and evapotranspiration rate) and the river flux observation system continued.

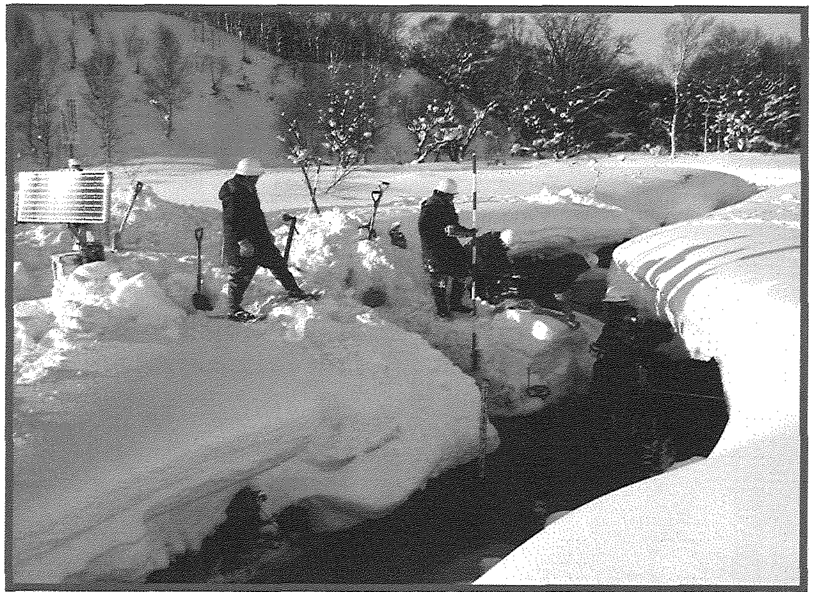
Groundwater levels and soil moisture were also observed using existing and newly drilled shallow boreholes of several meters to several tens of meters deep. Based on data from these observations and the results of water chemistry analyses using river water and precipitation, groundwater flow in the shallower part of the underground environment can be roughly understood and the recharge rate from ground surface to deep underground can be estimated. Groundwater pressures are continuously monitored and any influences due to the construction of the underground facilities are confirmed.

In the underground facilities, information on hydrogeological structures including the properties of water-conducting features and the inflow rate from the surrounding rock, are acquired in parallel with excavation. Laboratory experiments using rock samples obtained in the shafts are also conducted to investigate hydraulic properties.



Photographed at Hokushin Weather station

Meteorological apparatus



Photographed at P-4 station

River flux observation

Investigations in the 2006 Fiscal Year (4/17)

Development of techniques to investigate the geological environment (acquisition of geoscientific data: Groundwater chemistry)

Water is being sampled by squeezing drillcores and by collection from the shaft wall and chemical analyses is being conducted. Water is also sampled from the existing deep boreholes such as HDB-1-4 and HDB-6-11, and from shallow boreholes, and analyzed chemically. Sampling and chemical analyses of river water and precipitation are also conducted if necessary.

Photographed at Mizunami Underground Research Laboratory

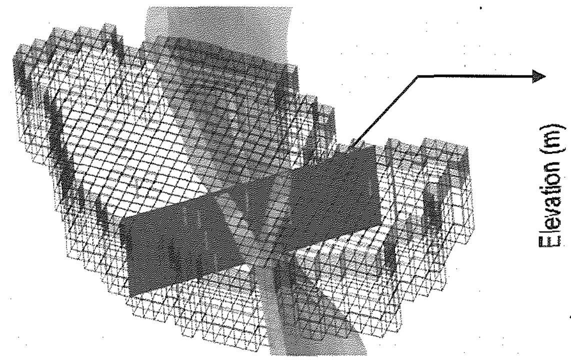
Water sampling from shaft wall

Investigations in the 2006 Fiscal Year (5/17)

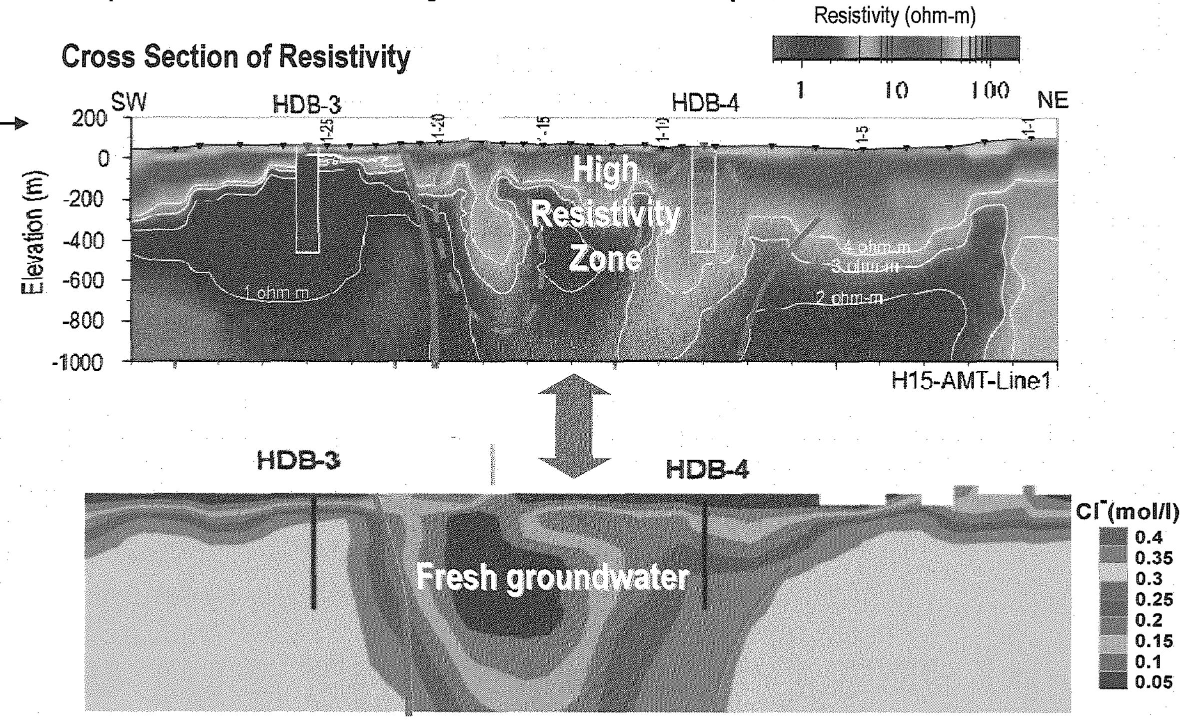
Evaluation of methodologies on investigations/analyses, and modeling the geological environment

In the Phase2 investigations, the consistency of models in different disciplines, such as groundwater flow and groundwater chemistry, is examined with a view to improving the reliability of the models of the geological environment developed in Phase 1. The changes in the geological environment during construction of the underground facilities are then predicted using these improved models. In addition, the applicability of the safety assessment methodology developed so far is examined using models and data relevant to the geological environment at Horonobe.

The applicability of models of the geological environment developed in Phase 1 is confirmed and they are improved based on data on the geological environment acquired during construction of the underground facilities. This allows the investigation methodologies to be systematized and models of the geological environment covering an area of several tens of square meters around the underground facilities to be developed.



Hydrochemistry model

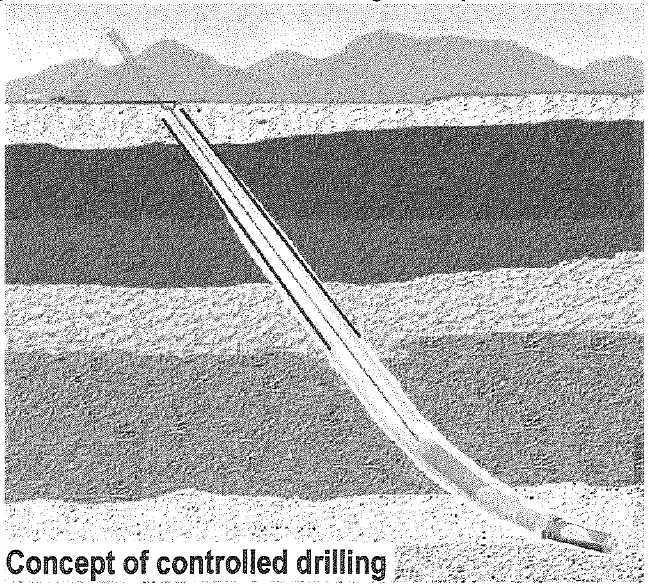


Investigations in the 2006 Fiscal Year (6/17)

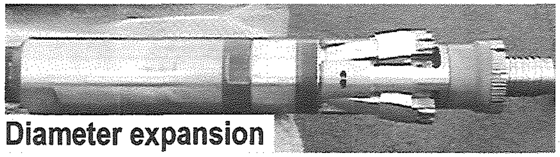
Development of investigation techniques and equipment

The applicability of the investigation techniques used in Phase 1 is being evaluated and the results are being summarized. As part of the continuing development of surface-based investigation techniques, drilling methods capable of controlling the angle and direction of boreholes (controlled drilling) are being examined. Controlled drilling towards the Omagari Fault has also been initiated in the Kami-Horonobe area.

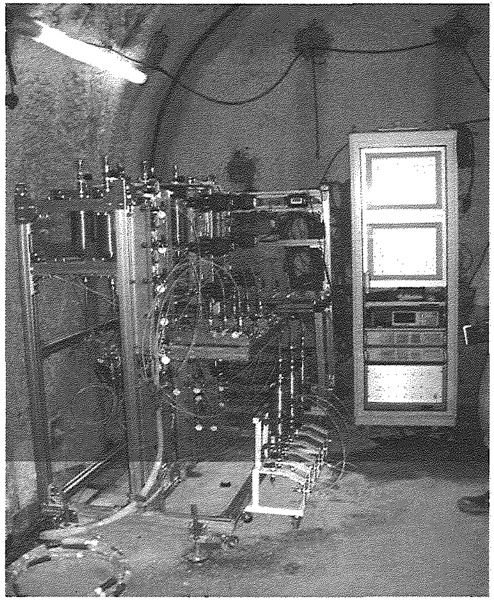
Development of the investigation techniques and equipment required for data acquisition in a range of disciplines using the underground facilities has been initiated. Concerning hydrogeology, equipment for measuring the hydraulic conductivity in a borehole drilled from the drift wall into the surrounding rock is also being designed and manufactured. For geochemistry, in-situ equipment capable of monitoring the pH, redox potential (Eh), etc. of groundwater is also being designed and manufactured. In rock mechanics, optical displacement meters for stable measurement of the displacement of the sedimentary rock on the long term during shaft and drift excavation are being developed.



Concept of controlled drilling



Diameter expansion



Photographed at Mizunami Underground Research Laboratory

Hydrochemical monitoring and water sampling equipment in the drift

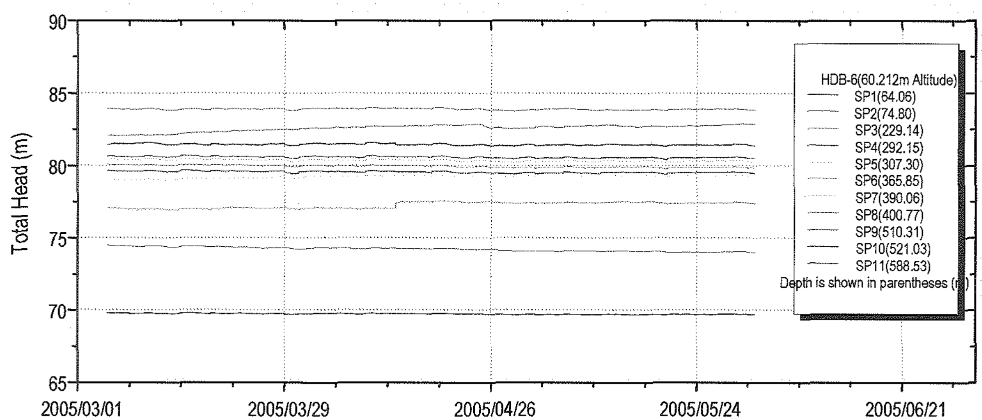
Investigations in the 2006 Fiscal Year (7/17)

Development of techniques for long-term monitoring of geological environment (Development of monitoring techniques in borehole)

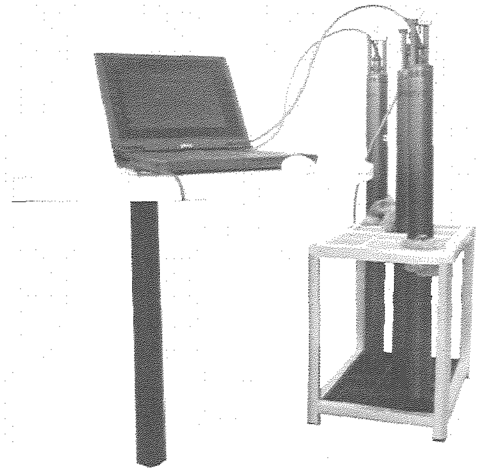
Observations of groundwater pressure/geochemistry are ongoing using long-term monitoring systems and a technique for monitoring influences originating from various investigation activities and from construction of the underground facilities are being developed.

Parts of the monitoring systems installed in Phase 1 are being upgraded by adding data transfer units; work on installing the long-term monitoring system in HDB-11 is ongoing from the previous fiscal year and monitoring of groundwater pressure, etc. has been initiated. Methods for processing and analysis of the monitoring data are being developed to provide an accurate understanding of the changes in groundwater pressures.

Several boreholes around 30 m in depth have been drilled around the shafts, high-precision tiltmeters and pore pressure meters have been installed in the boreholes and measurements initiated.



Monitoring results of porewater pressure

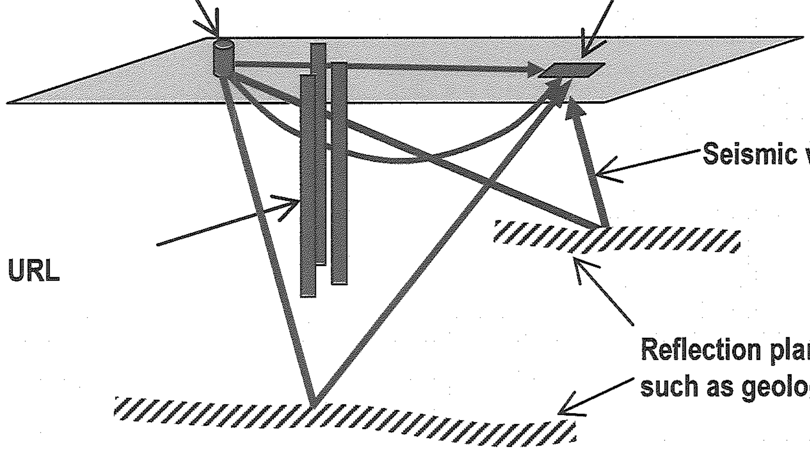


High-precision tiltmeters installed around the shaft

Investigations in the 2006 Fiscal Year (8/17)

Development of techniques for long-term monitoring of geological environment (Development of a remotely operated monitoring system)

Monitoring at existing observation points is continuing. In order to acquire detailed data in the vicinity of the underground facilities, short-term observations are conducted at the URL site.



Concept of a remotely operated monitoring system

Seismic wave transmitter
(Installed at HDB-3 Area)

Investigations in the 2006 Fiscal Year (9/17)

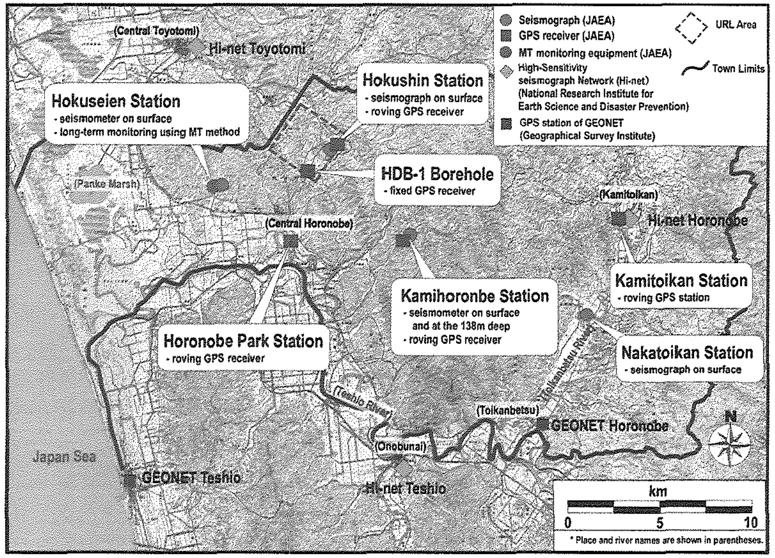
Studies on the long-term stability of the geological environment

- Studies on long-term changes in the geological environment

  Investigations of topography, deformation of geological formations and fault activity and analyses of microfossils and petrology/mineralogy using rock samples obtained from outcrops are being conducted. Information on crustal movements and climate changes from the Neogene to the Quaternary in and around Horonobe are being collected and classified. In addition, GPS and electromagnetic measurements are continuing and the extent of the crustal movements is being analyzed.

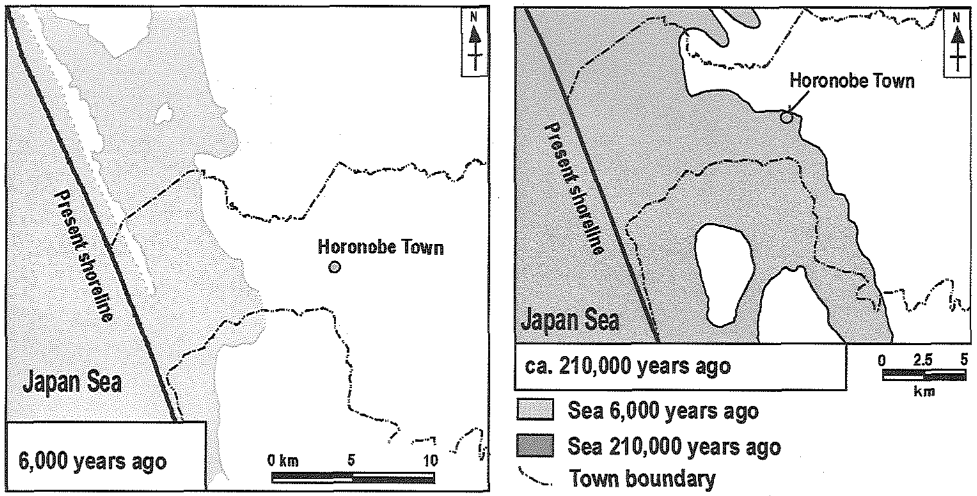
- Seismological studies

  Observations were made of micro-earthquakes in the Horonobe area and its surroundings using seismographs installed at ground surface and at the bottom of a 138 m-deep borehole. Based on these data, hypocenter distribution and geological structure in the deep underground are studied. In addition, information on past seismic activity in the Horonobe area is being collected and classified.



Base map is part of the 1:50,000 topographic map (Wakasakanai, Teshio, Toyotomi, Onobunai, Kami-sarufutsu, Pinneshiri)
Published by the Geographical Survey Institute of Japan

Observation stations in Horonobe

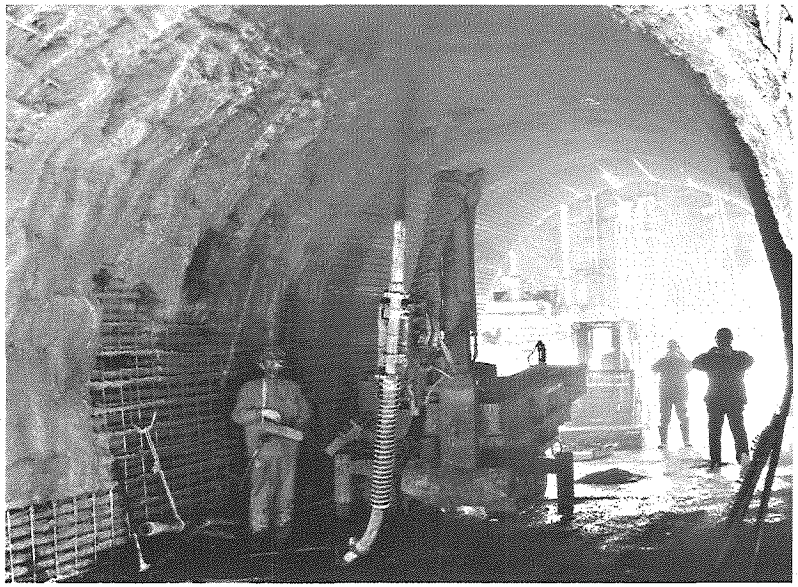


Reconstruction of past shoreline

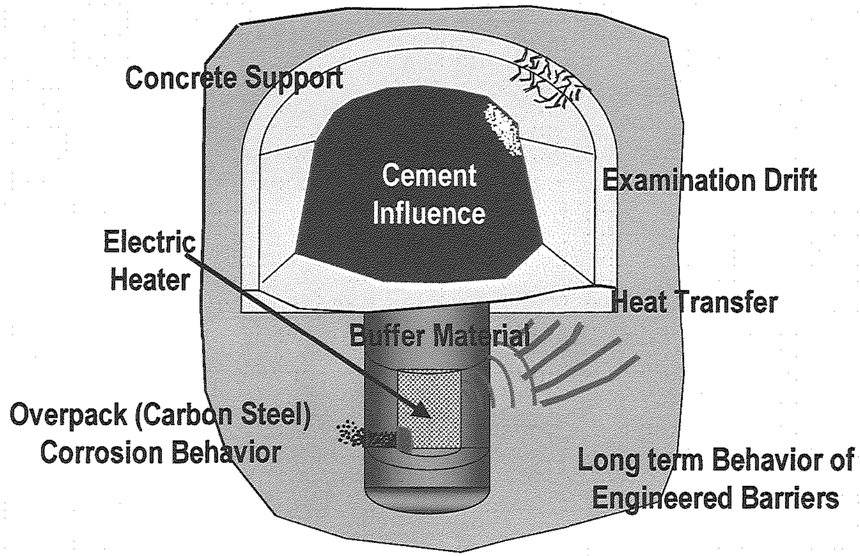
Investigations in the 2006 Fiscal Year (10/17)

Research and development on geological disposal technology

- Verification of the engineered barrier technology
  Regarding materials for tunnel support and tunnel sealing systems, laboratory tests on the workability of materials such as low-alkaline concrete are being conducted in the present fiscal year, to provide input for detailed planning of in-situ tests to be performed in the underground facilities in Phases 2 and 3.
- Confirming the applicability of EBS design methods
  The long-term behavior of the engineered barrier system and the surrounding rock are being studied and the design conditions are classified based on data on the geological environment obtained in Phase 1 and data from laboratory tests using drillcores and groundwater sampled from the borehole investigations conducted up to the 2005 fiscal year.



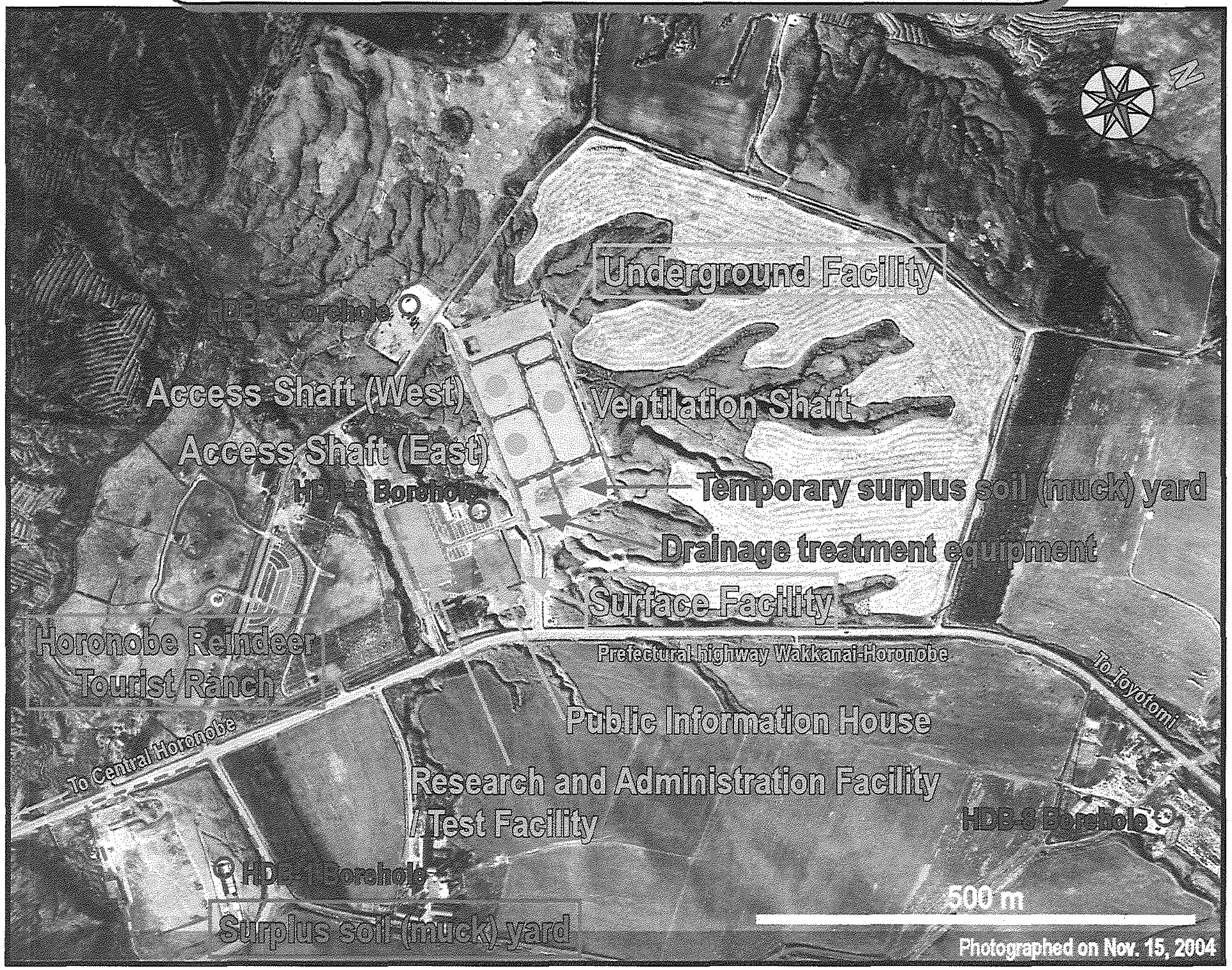
Workability test of low-alkaline concrete
(Shotcrete test in simulated tunnel)



Schematic illustration of long-term behavior of engineered barriers and the surrounding host rock

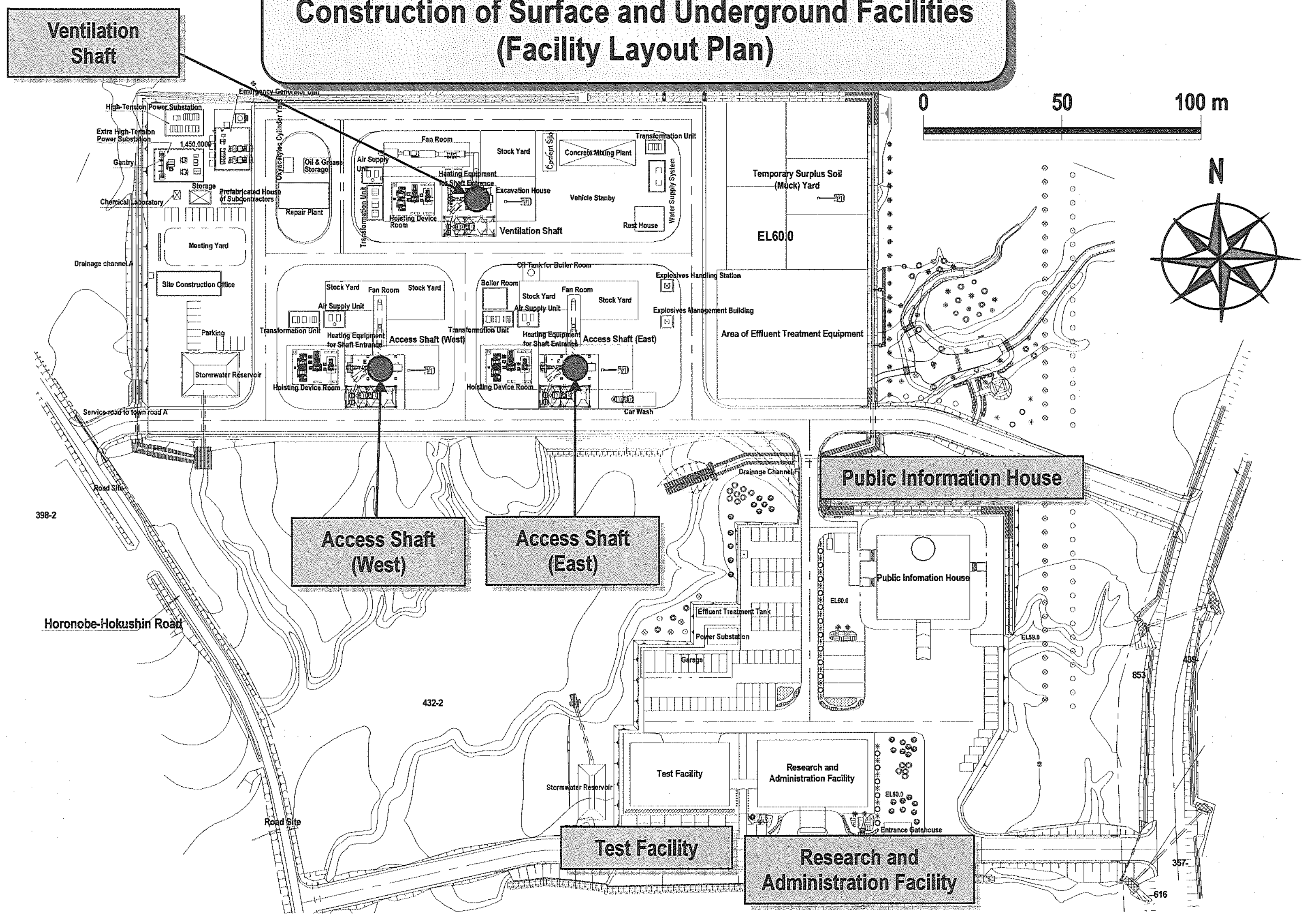
Investigations in the 2006 Fiscal Year (11/17)

Construction of Surface and Underground Facilities (URL area and the surroundings)



Investigations in the 2006 Fiscal Year (12/17)

Construction of Surface and Underground Facilities (Facility Layout Plan)



Investigations in the 2006 Fiscal Year (13/17)

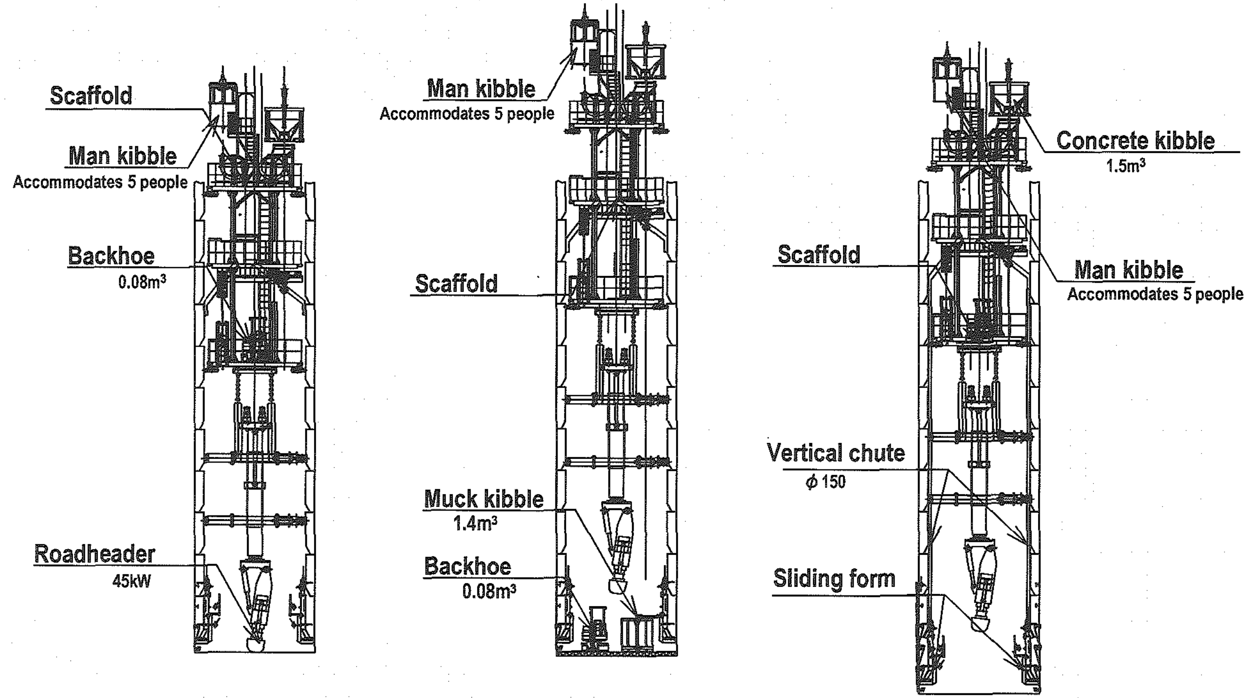
Construction of Underground Facilities

Excavation method

Roadheader
Full-face cutting

Supporting method

Short step
Excavation: 1m/step
Concrete lining: 2m/step

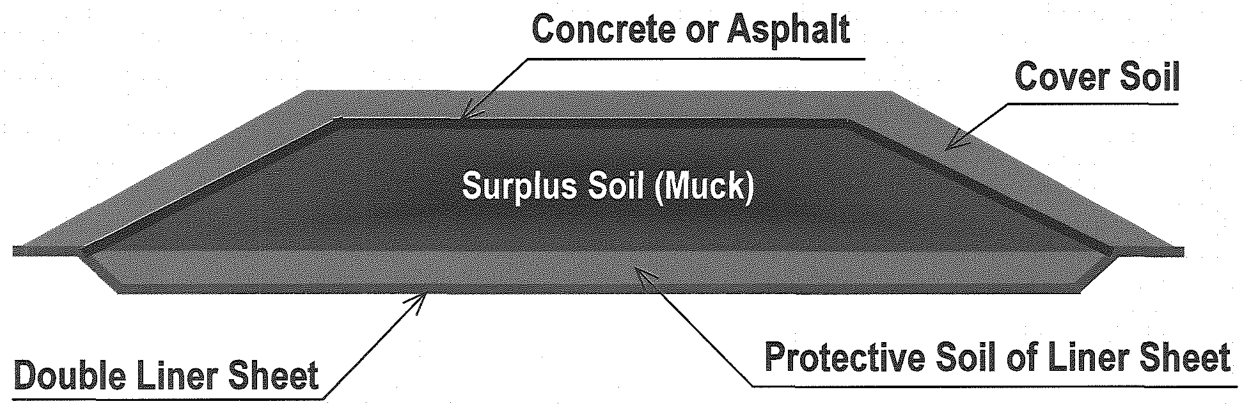


Excavation → Mucking → Concrete lining

Construction of shaft by mechanical excavation method with scaffold

Investigations in the 2006 Fiscal Year (14/17)

Construction of Surface and Underground Facilities (Surplus Soil (Muck) Yard)



Basic Plan

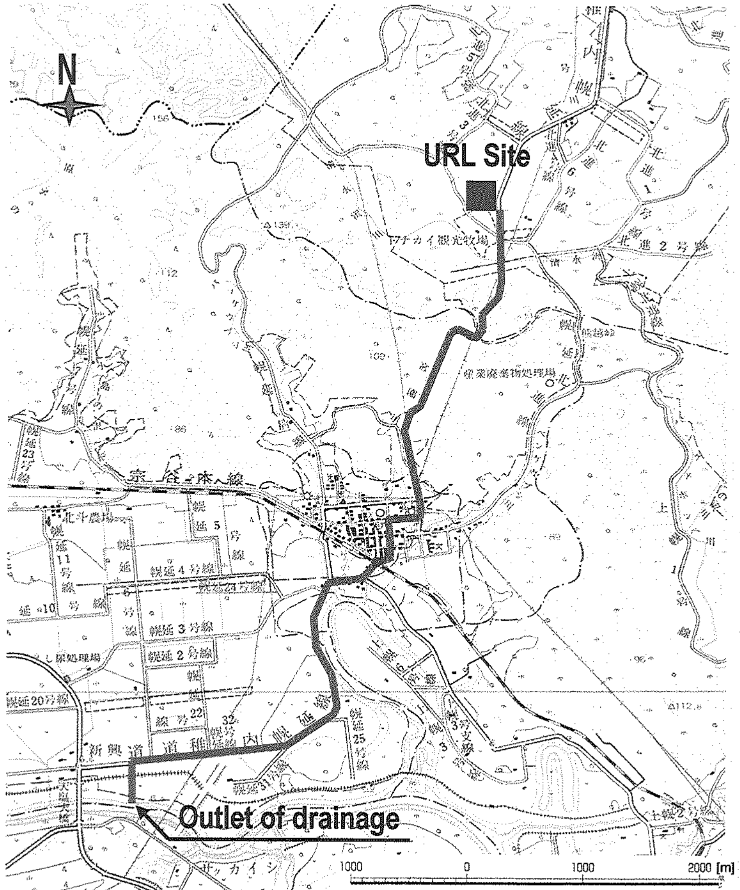
Environmental management is carried out in accordance with the "Soil Contamination Countermeasures Law", the "Water Pollution Control Law" and other applicable regulations.

Specification

- Construction area: approx. 23,000m^2
- Capacity: approx. 100,000m^3
- Impervious containment type pursuant to the Soil Contamination Countermeasures Law

Investigations in the 2006 Fiscal Year (15/17)

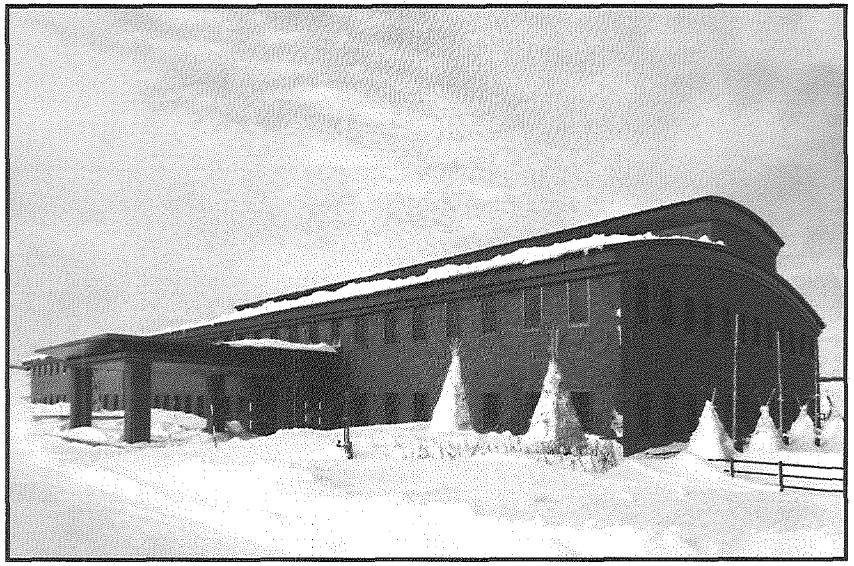
Construction of Surface and Underground Facilities (Route Plan of Drainage Line)



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

Investigations in the 2006 Fiscal Year (16/17)

Construction of Surface Facilities



Research and Administration Facility
& Test Facility

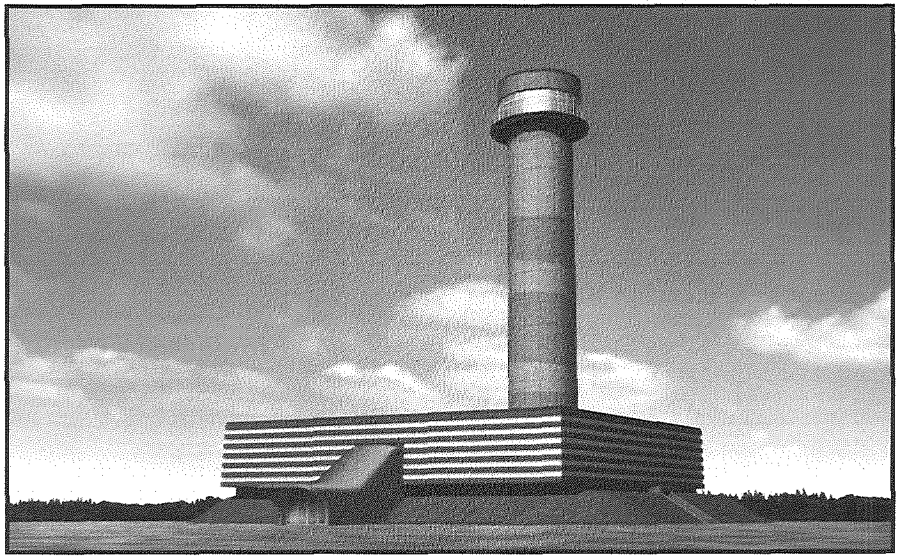
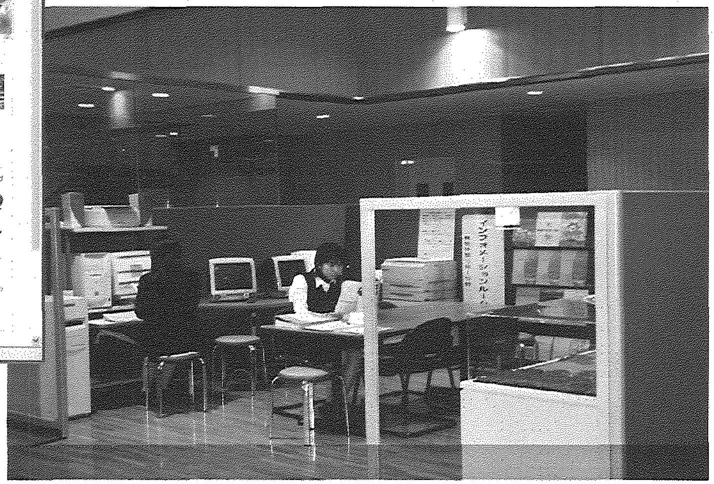


Image of Public Information House

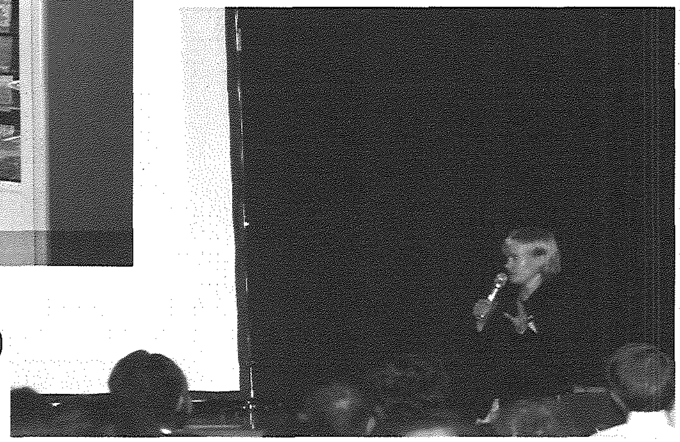
Investigations in the 2006 Fiscal Year (17/17)

Open Research

Website of JAEA Horonobe
(http://www.jaea.go.jp/04/horonobe)



Information Room
(Research and Administration Facility)



Information exchange with foreign researchers
(July 2005 at Horonobe community center)

国際単位系（SI）

表１．SI 基本単位

基本量	SI 基本単位	
	名称	記号
長さ	メートル	m
質量	キログラム	kg
時間	秒	s
電流	アンペア	A
熱力学温度	ケルビン	K
物質量	モル	mol
光度	カンデラ	cd

表２．基本単位を用いて表されるSI組立単位の例

組立量	SI 基本単位	
	名称	記号
面積	平方メートル	m^2
体積	立法メートル	m^3
速さ，速度	メートル毎秒	m/s
加速度	メートル毎秒毎秒	m/s^2
波数	毎メートル	m-1
密度（質量密度）	キログラム毎立法メートル	kg/m^3
質量体積（比体積）	立法メートル毎キログラム	m^3/kg
電流密度	アンペア毎平方メートル	A/m^2
磁界の強さ	アンペア毎メートル	A/m
（物質量の）濃度	モル毎立方メートル	mol/m^3
輝度	カンデラ毎平方メートル	cd/m^2
屈折率	（数の）1	1

表５．SI 接頭語

乗数	接頭語	記号	乗数	接頭語	記号
10^{24}	ヨタ	Y	10^{-1}	デシ	d
10^{21}	ゼタ	Z	10^{-2}	センチ	c
10^{18}	エクサ	E	10^{-3}	ミリ	m
10^{15}	ペタ	P	10^{-6}	マイクロ	μ
10^{12}	テラ	T	10^{-9}	ナノ	n
10^{9}	ギガ	G	10^{-12}	ピコ	p
10^{6}	メガ	M	10^{-15}	フェムト	f
10^{3}	キロ	k	10^{-18}	アト	a
10^{2}	ヘクト	h	10^{-21}	ゼプト	z
10^{1}	デカ	da	10^{-24}	ヨクト	y

表３．固有の名称とその独自の記号で表されるSI組立単位

組立量	SI 組立単位			
	名称	記号	他のSI単位による表し方	SI基本単位による表し方
平面角	ラジアン[(a)]	rad		$m \cdot m^{-1}=1$[(b)]
立体角	ステラジアン[(a)]	sr[(c)]		$m^2 \cdot m^{-2}=1$[(b)]
周波数	ヘルツ	Hz		s^{-1}
力	ニュートン	N		$m \cdot kg \cdot s^{-2}$
圧力，応力	パスカル	Pa	N/m^2	$m^{-1} \cdot kg \cdot s^{-2}$
エネルギー，仕事，熱量	ジュール	J	N・m	$m^2 \cdot kg \cdot s^{-2}$
工率，放射束	ワット	W	J/s	$m^2 \cdot kg \cdot s^{-3}$
電荷，電気量	クーロン	C		s・A
電位差（電圧），起電力	ボルト	V	W/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-1}$
静電容量	ファラド	F	C/V	$m^{-2} \cdot kg^{-1} \cdot s^4 \cdot A^2$
電気抵抗	オーム	Ω	V/A	$m^2 \cdot kg \cdot s^{-3} \cdot A^{-2}$
コンダクタンス	ジーメンス	S	A/V	$m^{-2} \cdot kg^{-1} \cdot s^3 \cdot A^2$
磁束	ウエーバ	Wb	V・s	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-1}$
磁束密度	テスラ	T	Wb/m^2	$kg \cdot s^{-2} \cdot A^{-1}$
インダクタンス	ヘンリー	H	Wb/A	$m^2 \cdot kg \cdot s^{-2} \cdot A^{-2}$
セルシウス温度	セルシウス度[(d)]	℃		K
光束	ルーメン	lm	cd・sr[(c)]	$m^2 \cdot m^{-2} \cdot cd=cd$
照度	ルクス	lx	lm/m^2	$m^2 \cdot m^{-4} \cdot cd=m^{-2} \cdot cd$
（放射性核種の）放射能	ベクレル	Bq		s^{-1}
吸収線量，質量エネルギー分与，カーマ	グレイ	Gy	J/kg	$m^2 \cdot s^{-2}$
線量当量，周辺線量当量，方向性線量当量，個人線量当量，組織線量当	シーベルト	Sv	J/kg	$m^2 \cdot s^{-2}$

(a) ラジアン及びステラジアンの使用は、同じ次元であっても異なった性質をもった量を区別するときの組立単位の表し方として利点がある。組立単位を形作るときのいくつかの用例は表４に示されている。
(b) 実際には、使用する時には記号rad及びsrが用いられるが、習慣として組立単位としての記号“１”は明示されない。
(c) 測光学では、ステラジアンの名称と記号srを単位の表し方の中にそのまま維持している。
(d) この単位は、例としてミリセルシウス度m℃のようにSI接頭語を伴って用いても良い。

表４．単位の中に固有の名称とその独自の記号を含むSI組立単位の例

組立量	SI 組立単位		
	名称	記号	SI 基本単位による表し方
粘度	パスカル秒	Pa・s	$m^{-1} \cdot kg \cdot s^{-1}$
力のモーメント	ニュートンメートル	N・m	$m^2 \cdot kg \cdot s^{-2}$
表面張力	ニュートン毎メートル	N/m	$kg \cdot s^{-2}$
角速度	ラジアン毎秒	rad/s	$m \cdot m^{-1} \cdot s^{-1}=s^{-1}$
角加速度	ラジアン毎平方秒	rad/s^2	$m \cdot m^{-1} \cdot s^{-2}=s^{-2}$
熱流密度，放射照度	ワット毎平方メートル	W/m^2	$kg \cdot s^{-3}$
熱容量，エントロピー	ジュール毎ケルビン	J/K	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1}$
質量熱容量（比熱容量），質量エントロピー	ジュール毎キログラム毎ケルビン	J/(kg・K)	$m^2 \cdot s^{-2} \cdot K^{-1}$
質量エネルギー（比エネルギー）	ジュール毎キログラム	J/kg	$m^2 \cdot s^{-2} \cdot K^{-1}$
熱伝導率	ワット毎メートル毎ケルビン	W/(m・K)	$m \cdot kg \cdot s^{-3} \cdot K^{-1}$
体積エネルギー	ジュール毎立方メートル	J/m^3	$m^{-1} \cdot kg \cdot s^{-2}$
電界の強さ	ボルト毎メートル	V/m	$m \cdot kg \cdot s^{-3} \cdot A^{-1}$
体積電荷	クーロン毎立方メートル	C/m^3	$m^{-3} \cdot s \cdot A$
電気変位	クーロン毎平方メートル	C/m^2	$m^{-2} \cdot s \cdot A$
誘電率	ファラド毎メートル	F/m	$m^{-3} \cdot kg^{-1} \cdot s^4 \cdot A^2$
透磁率	ヘンリー毎メートル	H/m	$m \cdot kg \cdot s^{-2} \cdot A^{-2}$
モルエネルギー	ジュール毎モル	J/mol	$m^2 \cdot kg \cdot s^{-2} \cdot mol^{-1}$
モルエントロピー，モル熱容量	ジュール毎モル毎ケルビン	J/(mol・K)	$m^2 \cdot kg \cdot s^{-2} \cdot K^{-1} \cdot mol^{-1}$
照射線量（X線及びγ線）	クーロン毎キログラム	C/kg	$kg^{-1} \cdot s \cdot A$
吸収線量率	グレイ毎秒	Gy/s	$m^2 \cdot s^{-3}$
放射強度	ワット毎ステラジアン	W/sr	$m^4 \cdot m^{-2} \cdot kg \cdot s^{-3}=m^2 \cdot kg \cdot s^{-3}$
放射輝度	ワット毎平方メートル毎ステラジアン	$W/(m^2 \cdot sr)$	$m^2 \cdot m^{-2} \cdot kg \cdot s^{-3}=kg \cdot s^{-3}$

表６．国際単位系と併用されるが国際単位系に属さない単位

名称	記号	SI 単位による値
分	min	1 min=60s
時	h	1h =60 min=3600 s
日	d	1 d=24 h=86400 s
度	°	1° =(π/180) rad
分	'	1' =(1/60)° =(π/10800) rad
秒	"	1" =(1/60)' =(π/648000) rad
リットル	l、L	$1l=1\ dm^3=10^{-3}m^3$
トン	t	$1t=10^3$ kg
ネーパ	Np	1Np=1
ベル	B	1B=(1/2)ln10(Np)

表７．国際単位系と併用されこれに属さない単位でSI単位で表される数値が実験的に得られるもの

名称	記号	SI 単位であらわされる数値
電子ボルト	eV	$1eV=1.60217733(49)\times10^{-19}J$
統一原子質量単位	u	$1u=1.6605402(10)\times10^{-27}kg$
天文単位	ua	$1ua=1.49597870691(30)\times10^{11}m$

表８．国際単位系に属さないが国際単位系と併用されるその他の単位

名称	記号	SI 単位であらわされる数値
海里		1海里=1852m
ノット		1ノット=1海里毎時=(1852/3600)m/s
アール	a	$1\ a=1\ dam^2=10^2m^2$
ヘクタール	ha	$1\ ha=1\ hm^2=10^4m^2$
バール	bar	$1\ bar=0.1MPa=100kPa=1000hPa=10^5Pa$
オングストローム	Å	$1\ Å=0.1nm=10^{-10}m$
バーン	b	$1\ b=100fm^2=10^{-28}m^2$

表９．固有の名称を含むCGS組立単位

名称	記号	SI 単位であらわされる数値
エルグ	erg	$1\ erg=10^{-7}\ J$
ダイン	dyn	$1\ dyn=10^{-5}N$
ポアズ	P	$1\ P=1\ dyn \cdot s/cm^2=0.1Pa \cdot s$
ストークス	St	$1\ St=1cm^2/s=10^{-4}m^2/s$
ガウス	G	1 G ^10^{-4}T
エルステッド	Oe	1 Oe ^(1000/4π)A/m
マクスウェル	Mx	1 Mx ^10^{-8}Wb
スチルブ	sb	$1\ sb=1cd/cm^2=10^4cd/m^2$
ホト	ph	$1\ ph=10^4lx$
ガル	Gal	$1\ Gal=1cm/s^2=10^{-2}m/s^2$

表10．国際単位に属さないその他の単位の例

名称	記号	SI 単位であらわされる数値
キュリー	Ci	$1\ Ci=3.7\times10^{10}Bq$
レントゲン	R	$1\ R = 2.58\times10^{-4}C/kg$
ラド	rad	$1\ rad=1cGy=10^{-2}Gy$
レム	rem	$1\ rem=1\ cSv=10^{-2}Sv$
X線単位		$1X\ unit=1.002\times10^{-4}nm$
ガンマ	γ	$1\gamma=1\ nT=10^{-9}T$
ジャンスキー	Jy	$1\ Jy=10^{-26}W \cdot m^{-2} \cdot Hz^{-1}$
フェルミ		$1\ fermi=1\ fm=10^{-15}m$
メートル系カラット		$1\ metric\ carat = 200\ mg = 2\times10^{-4}kg$
トル	Torr	1 Torr = (101 325/760) Pa
標準大気圧	atm	1 atm = 101 325 Pa
カロリー	cal	
ミクロン	μ	$1\ \mu=1\mu m=10^{-6}m$

（第７版，1998 年改訂）